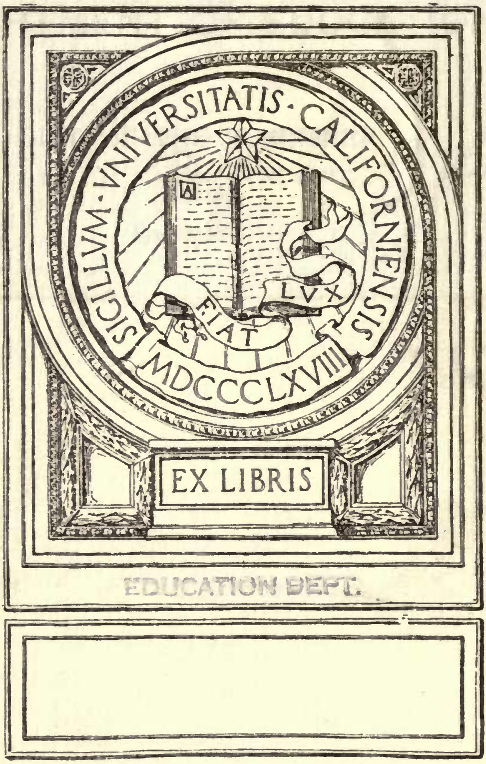
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STANDARD

SCHOOL PHYSIOLOGY

HYGIENE
ANATOMY

BY

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PREFACE.

The authors of this book, believing, as they do, that the study of no subject in the school curriculum can yield greater practical benefit to the student than the study of physiology, send it forth in the hope that it may add a little to the sum of human knowledge upon this important subject. It is almost incredible that the study of physiology, by pupils in public schools, should have been so long delayed, and that its great importance should have received so slow and inadequate a recognition.

This volume is believed to be adapted to the capacities and needs of students of academies, high schools, and the higher grammar grades.

In school systems where the subject has been studied by the pupils from the time of their entering school, as is required by law in some of the States, this book will be found adapted to use in grades as low as the VIIth (seventh year in school), or possibly the VIth. It is also thought to contain as much as should be required in public or preparatory schools.

Acknowledgments of the authors are due, and are freely made, to J. Howard Morgan, M.D., of Westerly, R. I., for his most painstaking reading and criticisms of the manuscript; also to Professor Elizabeth V. Gaines, of Adelphi College, Brooklyn, for her valuable criticisms and suggestions.

A most searching study of the diagrams and figures of a large number of physiologies—both those intended

for school use and for medical students—and of standard medical and anatomical works, convinced the authors that careful selections, from such standard works, of diagrams that fully illustrate the text would best serve the purposes of the book. Many of the diagrams are, therefore, reproductions of *the best* to be found in other works. The following well-known and excellent books have thus been drawn upon, and most hearty acknowledgments are extended to their publishers for the privilege:

Gray's "Anatomy" and Dalton's "Physiology," Lea Brothers & Co., Publishers.

Frey's "Histology," D. Appleton & Co., Publishers.

Sedgwick and Wilson's "Biology," Henry Holt & Co., Publishers.

Martin's "Human Body, Briefer Course," Henry Holt & Co., Publishers.

Waller's "Human Physiology," Longmans, Green & Co., Publishers.

Blaisdell's "Our Bodies, and How We Live," Ginn & Co., Publishers.

Lincoln's "Physiology," Ginn & Co., Publishers.

Raymond's "Physiology," W. B. Saunders, Publisher.

Foster and Shore's "Physiology," The Macmillan Company, Publishers.

"School Physiology Journal," Mrs. Mary H. Hunt, Publisher.

THE AUTHORS.

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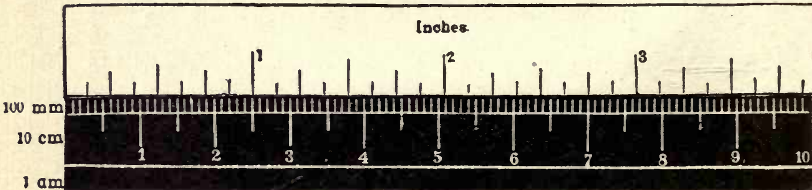
APPROXIMATE METRIC EQUIVALENTS.

I. Linear Measures.

1 micron = $\frac{1}{25400}$ or, more exactly, .00003937 + of an inch.
1 millimeter = $\frac{1}{25}$ or, more exactly, .03937 + of an inch.
1 centimeter = $\frac{2}{5}$ or, more exactly, .3937 + of an inch.
1 decimeter = ... 3.937 + inches.
1 meter = ... 39.37 + inches.

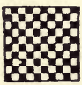
4 inches.



One Decimeter.

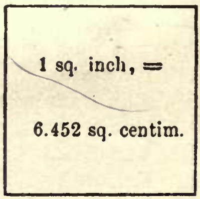
II. Surface Measure.

1 square centimeter = $\frac{3}{20}$ or, more exactly, .155 + of a sq. inch.



1 Square Centimeter.

$\frac{1}{2}$ inch square.



III. Capacity Measure.

1 liter = ... 1.0567 + quarts.

IV. Weight Measures.

1 gram = $\frac{1}{28}$ or, more exactly, .0353 — of an ounce.
1 kilogram = ... 2.2046 + pounds.
1 metric ton = w't of 1 cu. m. of water = 1.1023 tons.

V. Volume Measures.

1 cubic centimeter = ...061 cu. inch.
1 cubic decimeter = ... 61.022 cu. inches.

STANDARD SCHOOL PHYSIOLOGY.

CHAPTER I.

INTRODUCTION.

1. Anatomy is the science of the structure of the body.

Physiology is the science of the actions, or, technically, of the functions, of the living system in normal conditions.

An elementary knowledge of Anatomy is necessary to an understanding of Physiology. To be able to understand fully the contraction of a muscle or the action of a secreting gland, some knowledge of the part in question is necessary.

Physiology has two great practical applications: the first to Hygiene, or the art of preserving health; the second to Medicine, or the art of restoring it.

Medicine belongs to the province of the physician, who devotes his life to professional study, but Hygiene is the business of all.

The study of Physiology, with as much of Anatomy as is incidentally necessary, with special reference to its practical application to Hygiene, is the purpose of this book.

2. The Importance of a Knowledge of Hygiene.—What knowledge can be of greater importance than that which teaches how to prolong life and how to keep a sound body as the home of a sound mind!

In earlier times and among ignorant people disease was looked upon as a mysterious affliction to be warded off by spells and charms and drugs. To this day it is true, that in proportion to people's ignorance of the laws of health is their credulous belief in pills and potions and quackish impositions. Our wisest and best physicians rely less and less upon medicine and more and more upon the sanitary influence of Nature. When deformity or sickness is seen, we may be sure that Nature's laws have been violated. The principles of cause and effect hold good in the science of medicine and hygiene as well as in the science of physics and chemistry. The more perfectly these principles are understood, the better are we able to guard against the "ills that flesh is heir to," and so to gain for ourselves stronger bodies, clearer minds, nobler characters, and purer lives.

QUESTIONS ON THE INTRODUCTION.

1. What is Anatomy ?
2. What is Physiology ?
3. Why is an understanding of Anatomy necessary ?
4. What are the practical applications of Physiology ?
5. What is the purpose of this book ?
6. Why is a knowledge of Hygiene important ?

CHAPTER II.

CELLS AND TISSUES.

3. Human Physiology is the science that treats of the organic functions of human beings.

By organic functions we mean the uses and properties of the various parts which compose the body. These parts are called organs, as the eye is the organ of sight; the tongue, of taste. Some organs possess more than one function; the hand, besides being an organ of touch, is used to grasp objects, to play instruments, etc.

4. Tissues.—The body is composed of organs which vary a great deal in appearance and structure, as the skin, the muscles, and the bones.

Each organ of the body is composed of one or more tissues. Thus the muscles are composed of muscular tissue; the bones, of bony tissue; the tendons, of fibrous tissue.

Each of the tissues has a definite structure, and in health possesses certain definite properties; *i.e.*, muscular tissue never presents the properties of nervous tissue, or bony tissue those of mucous tissue.

5. Cells.—When a tissue is examined with a microscope it is seen to be composed of vast numbers of cells.

Cells of this kind are not enclosed spaces like the cells in honeycomb, but are small masses of translucent matter having one or more nuclei. (Fig. 1.) As these cells combine in various ways to form tissues, and tissues form the organs of a plant or an animal with life and

functions, it is evident that these cells are alive, or contain living matter.

So far as we know, the cell is the primary seat of life.

FIG. 1.—Different kinds of cells with nuclei.

Thus we have the body which is made up of various organs; the organs composed of tissues, and the tissues formed from cells, the primary seat of life.

6. Properties of Living Matter.—Life is that state or condition of matter which enables it to take into itself substances which act as food, and discharge worn-out matter which was once a part of itself.

This process is spoken of as *waste and repair*, and it is common to all living matter whether animal or vegetable.

Not only does living matter replace the materials worn out in the processes of life, but it also increases in size.

Living matter grows, gains in bulk and weight.

This may be said also of lifeless matter, but this growth is very different from that which takes place in living matter.

Lifeless matter grows by the addition of particles to the outer surface.

A crystal increases in size and weight by this process, which is known as growth by *accretion*.

Growth in living matter is accomplished by implanting new particles within its substance, where they become a part of the living mass.

This is spoken of as growth by *intussusception*.

Living matter also possesses the wonderful property of *reproduction;* that is, a mass of living matter may divide, and each part become a living organism possessing all the properties of living matter.

Thus it is seen that living matter possesses three properties; *viz.*, waste and repair, growth, and reproduction.

The state or condition of life cannot be explained. It is a mystery. Living matter loses nothing material when it dies. The weight and bulk are alike in either condition. It is therefore supposed that the difference is in the arrangement of the chemical elements which form the mass. This cannot be demonstrated, for any attempt to analyze living matter results in its death.

7. Composition of Living Matter.—All living matter contains substances known as proteids.

These are complex chemical compounds of carbon, oxygen, hydrogen, nitrogen, sulphur, and often phosphorus. Although these compounds are always found in living matter, it by no means follows that all proteid substances are alive. The white of egg is largely proteid matter, but possesses no life.

The power to manufacture proteids out of other substances belongs exclusively to living matter, and these substances are found nowhere in nature except through its agency.

8. Living and Lifeless Matter in Organisms.—If a plant or an animal be examined, it at once becomes apparent that portions of the matter of the organism are entirely lifeless.

The outer bark of a tree; the beak, claws, and feathers of birds; the hair, nails, and outer layers of the skin of the human body, are without life. The shells of oysters, lobsters, crabs, etc., serve as covering and protection, but are entirely without life.

Further examination shows that much of the matter contained within the organism is lifeless. The heart of the tree possesses but little life and acts simply as a

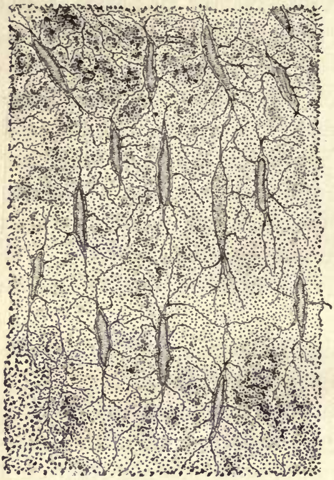


FIG. 2. — Bone tissue, showing living branching bone-cells scattered through the lifeless matrix.

support. So also the earthy part of the bones is without life.

Bone-cells (Fig. 2) are scattered throughout bone tissue, and send out shoots or branches which join one with the other; but the matter lying between the cells is without life, like the oyster's shell.

The minute fibers of the muscles are also covered with a thin covering or sheath which is lifeless.

Fat is also lifeless matter deposited in and about the tissues of the body.

Not only may fat and other lifeless matter be deposited in the tissues, but they may be found within the cell-bodies. (Fig. 3.) Crystals, grains of starch, and various coloring matters find lodgment in the cells which form the various tissues of the body.

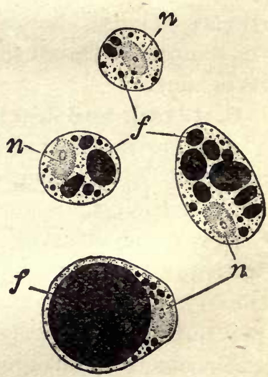


FIG. 3.—Groups of adipose cells, showing drops of fat within the cell-bodies; *f*, fat drops; *n*, nuclei.

There is almost no limit to the number of substances that may be deposited in and around living matter.

Lifeless matter which enters into the formation of organized structures tends to increase with age.

This accounts for the suppleness and vigor of youth and the stiffness and decrepitude of the aged.

9. Similarity of Tissues in Early Life.—There is a wonderful similarity of the tissues of an organism during its early development. For instance, a leaf from a bush shows a delicate framework of woody tissue (the veins) which supports the green pulp of the leaf, and the whole is covered with a thin transparent skin. When the leaf is still in the bud the cells which form the framework, the pulp, and the skin resemble each other closely, and it is difficult to determine into which tissue they will ultimately develop.

This is equally true in the early development of animals. The cells of the mass are similar and seem to form one homogeneous tissue. Later the cells change in shape and size, and unite to form the tissues which compose the various organs of the body. This is a slow process, comparatively speaking, for many of the changes are at birth incomplete, and, according to the length of life of the animal, require a longer or shorter time for completion. Those that live but a short time mature rapidly, while in man the change is not complete until several years have passed.

This process is known as *differentiation.*

In early life tissues are undifferentiated; later they are partially differentiated. In some low forms of animal and vegetable life the tissues are never differentiated, but form a homogeneous mass.

10. Construction of Cells.—A cell is a small mass of living matter, usually surrounded by a membrane, or cell-wall, and having within its substance a rounded body called the nucleus. (Fig. 4.)

The body of the cell is composed of a substance called protoplasm.

This is a transparent, jelly-like substance, in which

are suspended minute granules of a darker color. This somewhat viscid mass is supposed to have a definite structure, but its precise nature is in dispute.

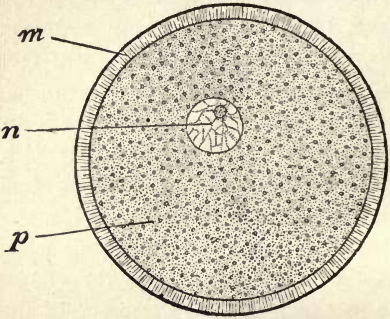


FIG. 4.—Egg of starfish, showing structure of cell; *m*, membrane; *n*, nucleus; *p*, protoplasm.

By some it is said to resemble a sponge in structure; others describe it as like foam, the minute cavities in the foam being filled with liquid.

The nucleus is a rounded body suspended in the protoplasm.

It consists of a transparent substance of a higher refractive power than the cell-body, surrounded by a very thin cell-wall, or membrane. Within the nucleus a second spot of a still higher refractive power is often seen, and is called the *nucleolus*.

The membrane, or wall of the cell, is rather a thick coating or sac which surrounds the protoplasm, which it closely resembles. It is formed from the protoplasm, and is without life, like the outer layers of the skin and the hair and nails of the body.

11. Development of the Cell.—The eggs of many animals are typical illustrations of single, undeveloped cells.

The eggs of the frog appear to the eye as dark spots embedded in a jelly-like mass which floats in stagnant ponds. (Fig. 5.)

Each one of these dark spots is an egg, or cell, which, under the right conditions, will develop into a frog.

If one of these cells be watched during development,

there is seen first a division of the protoplasm and the nucleus within the surrounding membrane or cell-wall.

The cell-membrane then contains two cells with a line of division, or segmentation, between. The division continues into fourths, eighths, sixteenths, thirty-seconds, etc., the whole forming a granular mass of cells similar to the first or primal cell. This is essentially what occurs in the germ-cells of all plants and animals. (Fig. 6.) The cells of the mass soon begin to differentiate. There is a change in the size, shape, and color of the cells. They arrange themselves according to the functions they are to perform during the development

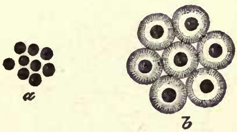


Fig. 5.—Frogs' eggs; *a*, before being discharged from the body; *b*, after being discharged from the body.

of the body and in after life, thus forming the various tissues. During this formation the cells throw out from themselves a substance which forms the stroma, or groundwork in which they are finally embedded. In bone and cartilage, for instance (Fig. 2), the cells are widely separated, the intervening substance being lifeless matter which is kept in repair by the activity of the living cells of the tissue.

In tissues which have little or no stroma the protoplasm of the cells is not in direct contact. Each cell is surrounded by its cell-wall, which keeps it separate and distinct.

Thus from a single cell or germ the body of the living plant or animal is formed. The primal cell multiplies

by repeated segmentation, the cell-mass differentiates into the various tissues, the tissues form the several

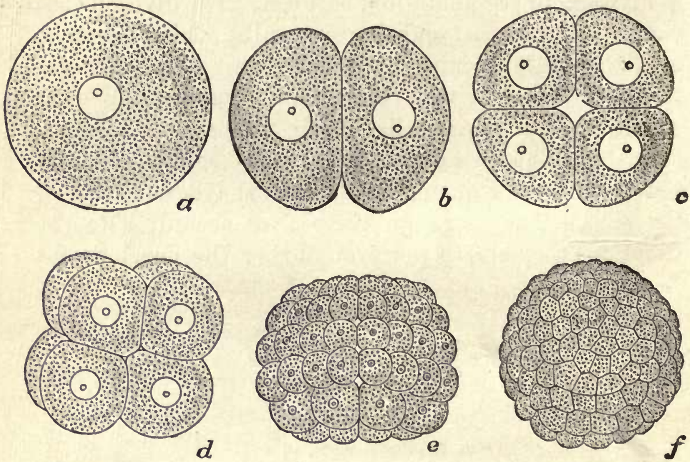


FIG. 6.—Segmentation of egg during its early development; *a*, the germ-cell; *b*, division into two cells; *c*, division into four cells; *d*, division into eight cells; *e*, *f*, later stages of development.

organs, and the organs collectively form a complete living organism.

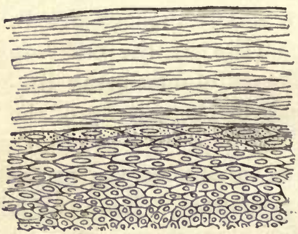


FIG. 7.—Section of the skin—epidermis—showing the flat epithelial cells.

The more important of the cells which enter into the formation of the tissues are those of the skin and mucous membranes, the muscles, connective tissue, the bones, the blood, and the brain. The cells of the skin and mucous membranes are called epithelial, and vary in form according to location and function. (Fig. 7.) On

the surface of the body they are flat, somewhat irregular in outline, with a nucleus near the center.

Those of the mucous membrane of the diges-

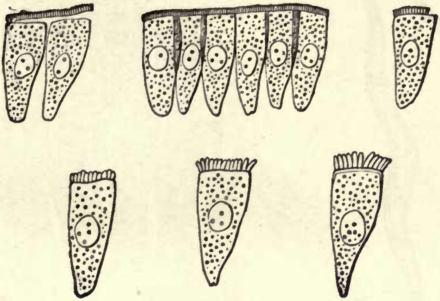


FIG. 8.—Columnar epithelium.

tive tract are spoken of as columnar (Fig. 8), while

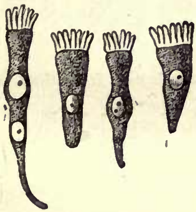


FIG. 9.—Cillated epithelium.

those of the air passages are ciliated (Fig. 9), having fine, hair-like processes on the surface which wave in certain directions.

Voluntary muscular tissue is composed of bundles of striated fibers. (Fig. 10.)

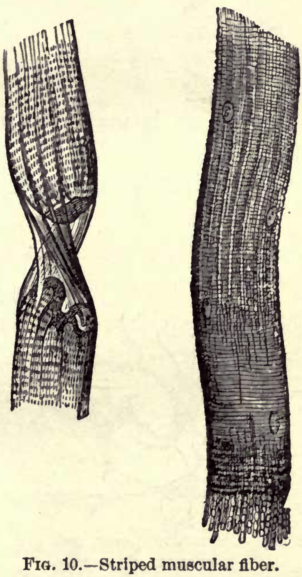


FIG. 10.—Striped muscular fiber.

Involuntary muscles are made up of elongated cells. (Fig. 11.)

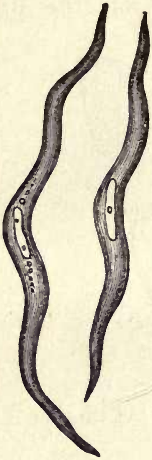


FIG. 11.—Elongated involuntary muscular cells.

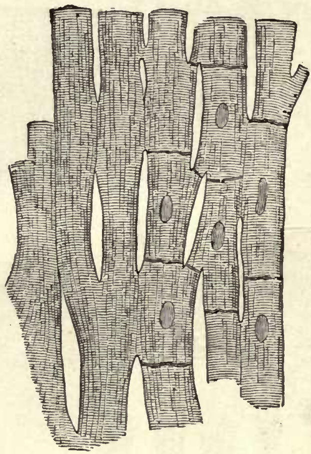


FIG. 12.—Muscle cells from the heart.

The heart is made up of block-shaped cells. (Fig. 12.)

Connective tissue forms the framework of the glands

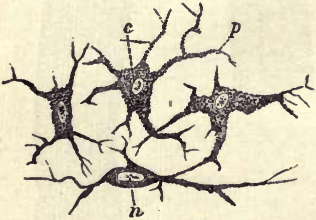


FIG. 13.—Connective tissue cells; *c*, cell; *p*, process; *n*, nucleus.

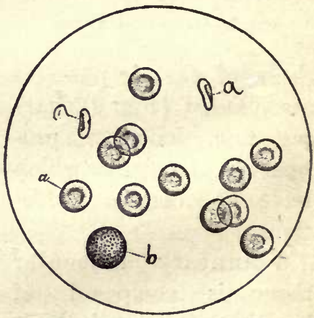


FIG. 14.—Human blood cells; *a*, red cells; *b*, white cell.

of the body, the sheaths of muscles, and the deep layers of the skin.

It is composed of fine white fibers, in the meshes of which lie the connective tissue cells.

They are the stellate, or branching cells. (Fig. 13.)

For bony cells see Fig. 2.

The blood must be considered as a tissue and contains two kinds of cells: the red corpuscles, which are disks with depressed centers, and the white corpuscles, which are rounded bodies of a grayish-white color. (Fig. 14.)

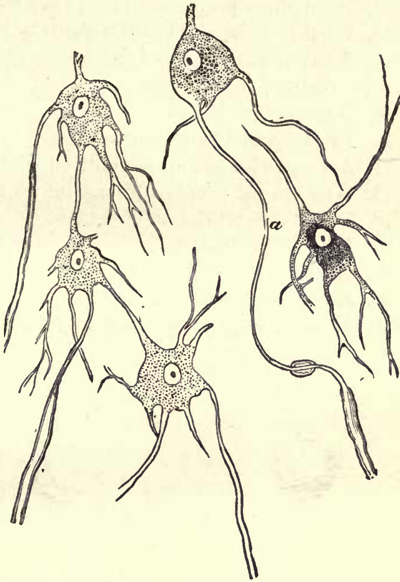


FIG. 15.—Cells from human brain.

The brain cells are known as unipolar or multipolar, according to the number of processes.

They are of a grayish-white color, with a nucleus and a nucleolus. (Fig. 15.)

QUESTIONS ON CELLS AND TISSUES.

1. Define Human Physiology.
2. What is meant by organic functions?
3. Define organs. Illustrate.
4. Of what is each organ composed?
5. What is the primary seat of life?

6. Describe a cell.
7. What is meant by the processes of waste and repair ?
8. What is the difference between growth by accretion and growth by intussusception?
9. What three properties does living matter possess?
10. What is meant by reproduction?
11. What is the supposed difference between living and lifeless matter?
12. What are proteids?
13. Are all proteid substances alive?
14. Are organisms composed entirely of living matter? Illustrate.
15. Why are old people stiff and infirm ?
16. Define differentiation of tissues.
17. What is protoplasm ?
18. Describe the nucleus of a cell.
19. How does the cell develop ?
20. Mention some of the more important cells.

CHAPTER III.

THE SKELETON.

12. The Skeleton.—The skeleton is the bony framework to which the soft or fleshy parts of the body are attached. It gives form and stability to the structure, and enables us to perform the labor necessary for our existence. It is also a means of protection, preserving the vital organs from the injuries they might receive if they were external to the skeleton instead of being within its bony cavities.

Shapes.—The bones vary in shape and structure according to the purposes they are intended to serve. For instance, the bones of the skull are of a shape and structure to retain and protect the brain; those of the spinal column to sustain weight; those of the arm act as levers.

13. Composition of Bone.—Bone is composed of two substances: animal and mineral.

The animal portion gives to the bone a certain amount of spring, or flexibility, and the mineral, or earthy part, furnishes stability and solidity.

The proportion of these substances varies during life.

In childhood and youth the animal part predominates, and the bones are springy and are not easily broken.

In old age the earthy matter predominates, and the bones are brittle and do not so readily unite when fractured. (See foot-note.)

NOTE.—Authorities differ in regard to this point; some authors claim that the proportion of animal and earthy matter is the same

If a long bone, like a rib or one of the bones of the arm, be put into a solution of hydrochloric acid, the earthy parts, which are phosphates of lime, soda, and potash, are dissolved; and, although the bone retains its form, what remains of it is soft and flexible and can be bent or tied in a knot.

If a bone be placed in a fire, the animal part is burned away, and the earthy part is easily broken or crumbled into small pieces.

14. Structure.—Bone is of a yellowish or ivory-white appearance ; hard, almost stone-like to the touch ; very strong, yet comparatively light. The reason for this lightness becomes apparent when the bone is cut across, for it is found to be hollow. (Fig. 16.)

If it be a long bone, like the bone of the thigh, the cavity is quite large, being filled with a grayish-pink, greasy semi-solid, called marrow, while the ends, which are enlarged to form the joints, are composed of a hard outer layer and a spongy or porous interior. (Fig. 16.)

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in infancy, youth, and old age, the lightness of the bones of the aged being due to the diminution of the whole bony structure, which leaves the bone porous and fragile.

Thus Macalister says: "The composition of fully formed bone varies very little with age. When all adhering unossified material is removed, the proportions are the same in the radius of a child of seven, an adult of forty, and an old man of eighty." He states that when bone has been decalcified it is found to have lost "two-thirds of its weight." In old age, when tissue-nutrition is impaired, and movements are slow, the bones become porous and more fragile, not from alteration in composition but from diminution in the amount of tissue; hence they become lighter. The femur of a woman of 103 years weighed 145 grams, while that of a woman of forty, of the same size, weighed 350 grams. In children what is known as the "green-stick" fracture is sometimes seen. The bone is bent and splintered without completely separating. In old age fracture is complete, the bone showing a clean break, as when the stem of a clay pipe is snapped.

This is known as cancellous tissue, and is found largely in the irregular bones, such as the vertebræ.

This formation furnishes breadth of surface for articulation, while the bone is thus made light yet abundantly strong.

15. Growth of Bone.—The bone in health is covered with a thin, parchment-like layer known as the periosteum, which is composed of fibrous tissue, and completely covers the bones except over the articular surfaces.

From this covering the bone draws its nourishment; little blood-vessels are given off and penetrate the bone, supplying the materials for growth and repair.

If the periosteum be loosened or removed, the part of the bone directly beneath is likely to die and to separate from the healthy portion, while from the loosened periosteum new bone is formed.

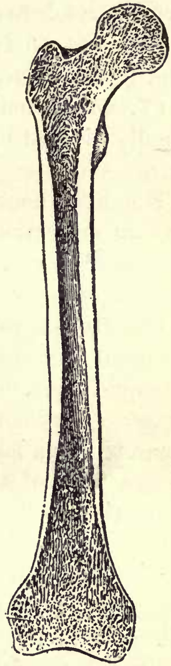

FIG. 16.—Longitudinal section of femur, showing cancellous tissue and marrow cavity.

This function is taken advantage of by the surgeon, and sometimes the whole bone will be replaced, if the damaged parts be carefully removed and the periosteum be left in position. Bone when cut or broken bleeds readily, the blood welling up from minute cavities in the bone substance. These little cavities connect with each other, and a perfect circulation is maintained, the blood being carried throughout the whole structure.

16. Repair of Bone.—When a bone is broken, blood is poured out about the injured parts, producing tender-

ness and swelling. Later on this blood is absorbed, and a sticky, gelatinous substance is thrown out around the broken ends. This is known as callus, and it finally becomes hardened into bone, uniting the two parts strongly and firmly. Often, enough of this callus is thrown out to form a knob or bunch, which may be readily felt beneath the soft parts.

17. Classification.—The bones of the skeleton are usually divided into three classes: long, flat, and irregular.

The long bones act largely as levers; the flat bones furnish protection and attachments for muscles, and the irregular bones sustain weight, supply muscular attachment, and enter largely into the formation of joints.

18. Bones of the Skull.—The bones which form the skull or cranium are, with the exception of the sphenoid and ethmoid, of the variety known as flat bones. They consist of two tables or plates which are separated by a layer of cancellous tissue, such as is found in the ends of the long bones, thus affording a double protection to the contents of the skull.

There are eight bones which enter into the formation of the cranium: frontal, occipital, two parietal, two temporal, sphenoid, and ethmoid. (Fig. 17.)

The FRONTAL BONE forms the forehead and joins the parietal bones at the top, the sphenoid bone at the sides, and the sphenoid and ethmoid bones at the base. It enters into the formation of the sockets for the eyes, and to it are attached the bones of the face and nose.

The OCCIPITAL BONE forms the base and back of the skull. It rests upon the first of the cervical vertebræ, and presents at this point a large opening known as the *foramen magnum,* through which the spinal cord and nerves enter the skull cavity and connect with the brain. This bone joins the parietal bones above and at

the sides, and unites with the temporal bones along its lower border. The part in front of the *foramen magnum* joins the body of the sphenoid bone.

The PARIETAL BONES form the arch of the cranium. They unite in the median line and join the frontal bone

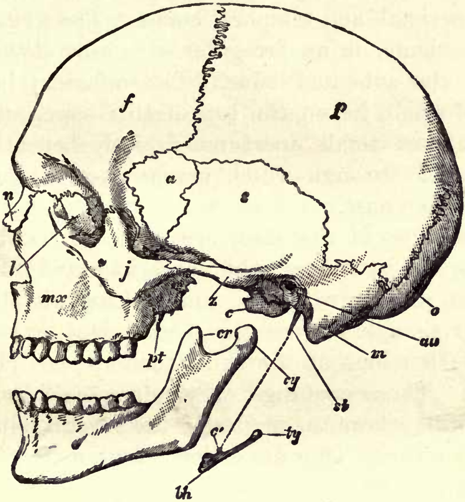

FIG. 17.

Side view of skull: *f*, frontal bone; *p*, parietal; *o*, occipital; *a*, wing of sphenoid; *s*, flat part of temporal; *c*, *m*, *st*, other parts of temporal; *au*, opening of the ear or external auditory canal; *z*, process of temporal passing to *j*, the malar bone; *mx*, the upper jaw bone; *n*, nasal bone; *l*, lachrymal; *pt*, part of the sphenoid. The lower jaw bone extends downward; *cy*, its process which articulates with the temporal; *cr*, its process to which muscles of mastication are attached; *th* and *ty*, hyoid bone.

anteriorly. Posteriorly they unite with the occipital bone, and at the sides they are attached to the temporal and sphenoid bones.

The TEMPORAL BONES form the sides of the cranium. In the outer surface of these bones is found the opening of the auditory canal, or canal of hearing, which leads

into what is known as the petrous portion of the bone, in which are situated the organs of hearing. It unites with the parietal, occipital, and sphenoid bones. The SPHENOID bone has wings, which give it somewhat the appearance of a bat. These wings enter into the formation of the sockets for the eyes, and join with the frontal, parietal, and temporal bones. The ETHMOID, or sieve-like bone, is an irregular structure situated in front of the sphenoid bone. The olfactory bulbs, or organs of smell, lie on the top of this bone, and there are numerous small apertures directly beneath these little bodies through which nerves pass to the inner surface of the nose.

All the bones of the skull are firmly joined together by rough, saw-like edges, which interlock and form what are known as sutures, which make the skull almost as strong as though it were one piece. During early life there are portions of the skull that are not closed in by bone. These openings, or "soft spots," are found at the points where the angles of the several bones subsequently unite. They are called "fontanelles," and do not close entirely until the early years of childhood.

19. Bones of the Face.—There are fourteen bones that enter into the formation of the face: two MALAR, or cheek-bones; two NASAL, or nose-bones; two superior and one inferior MAXILLARY, or jaw-bones; two PALATE bones; two LACHRYMAL bones; one VOMER; and two TURBINAL BONES. (Fig. 17.)

The MALAR is the large prominent bone at the outer side of the face and below the eye. In some races, as the Chinese and Indian, these bones are particularly prominent, and give to these people a look peculiar to the race. The SUPERIOR MAXILLARY bones hold the upper teeth and form the face below the malar bones. A horizontal plate projects from the inner side of each

to form a part of the roof of the mouth. The INFERIOR MAXILLARY bone holds the lower teeth. It joins the temporal bone in front of the ear to form the joint which allows of the up-and-down movement of the jaw. The PALATE BONES form, with the superior maxillary bones, the roof of the mouth. They also enter into the formation of the nasal cavity.

The LACHRYMAL BONES are two small, delicate bones situated at the inner side of the socket of the eye. There is in each a small opening through which passes the nasal duct which leads from the eye to the nasal cavity.

The TURBINAL, or spongy, bones are two thin, scroll-like bones attached to the inner side of the palate bones where they enter into the formation of the nasal cavity. They are light and spongy and the nerves of smell are distributed over them.

The VOMER, plowshare, divides the nasal cavity, thus forming the two nostrils. The NASAL BONES form the arch or bridge of the nose. They unite with the superior maxillary bones at the sides and with the frontal bone above.

The HYOID BONE is a small U-shaped bone to which the roots of the tongue are attached. It can be felt in the neck just below the inferior maxilla. It does not articulate with any other bone.

20. Bones of the Upper Extremity.—The bones of the shoulder are included in this group, making in all thirty-two bones. These are divided into three groups: the arm, which includes the SCAPULA, the CLAVICLE, and the HUMERUS; the forearm, which includes the ULNA and RADIUS; and the hand, which includes the eight CARPAL BONES, the five METACARPAL BONES, and the fourteen PHALANGEAL BONES. (Fig. 18.)

The SCAPULA, or shoulder-blade, is a thin, flat, triangular-shaped bone (Fig. 18) attached to the outer and

back part of the chest-wall by muscles. At its upper and outer angle the bone becomes thickened and rounded and forms a cup-shaped depression into which fits the rounded end of the humerus, forming the shoulder joint. From the posterior surface rises a ridge of bone which extends upward, outward, and forward. This is known as the spine of the scapula, and it unites with the clavicle above the shoulder joint, forming an arch to which the large muscles of the shoulder are attached.

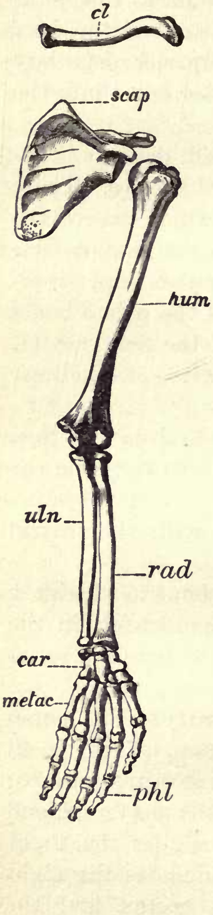

FIG. 18.—Bones of the arm, forearm, and hand.

The CLAVICLE, or collar-bone (Fig. 18), is a long bone bent upon itself so as to resemble somewhat the italic letter "*f*" placed upon its side. It extends from the sternum or breast bone, in front, to the spine of the scapula at the point of the shoulder. It prevents the shoulder from falling forward when the muscles of this part of the body are brought into action. It is perhaps more frequently broken than any of the bones, because of frequent blows and falls on the shoulder. It also heals more rapidly than any other bone.

The HUMERUS is a long bone that extends from the shoulder to the elbow. At the upper end is the rounded surface or head which fits into the cup-shaped depression in the scapula. Its

lower end shows two articulating surfaces for the bones of the forearm. (Fig. 18.)

The ULNA is situated on the inner side of the forearm, and is attached to the humerus by a hinge joint which allows a to-and-fro movement. It has no articulating surface for the wrist-bones, and is joined to them by ligaments only. Its lower end is small and has an articular surface on its outer side where it joins the radius.

The RADIUS, which revolves about the ulna, is on the outer side of the forearm. Its upper end is attached to the humerus by what is known as a ball-and-socket joint. To its lower end are attached the bones of the wrist, and on its inner side is a small surface for articulation with the ulna. It is this arrangement, together with the ball-and-socket joint at the elbow, which allows the hand to rotate with such freedom. (Fig. 19.) The CARPAL BONES are eight in number and form the wrist. They are irregular in form and closely bound together by ligaments, yet not so closely that they cannot move upon each other during the turning and bending of the wrist. (Fig. 19.)

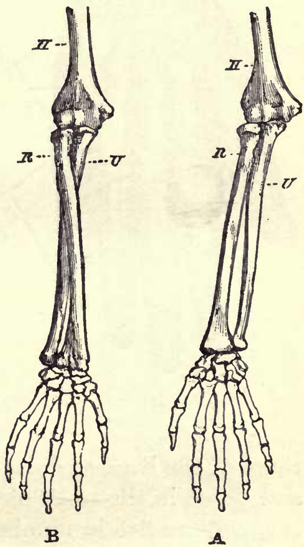

FIG. 19.—Showing joint at elbow with rotation of forearm; *a*, showing back of hand ; *b*, showing palm ; *h*, humerus; *r*, radius; *u*, ulna.

The METACARPAL BONES are five in number and form the hand. They are joined to the wrist-bones

above, and to their lower extremities are attached the phalanges. They are firmly bound together by muscles and strong fibrous bands. (Fig. 20.)

The PHALANGES, or finger-bones, are fourteen in number and form the fingers. Each finger contains three, the thumb two, of these bones. (Fig. 20.)

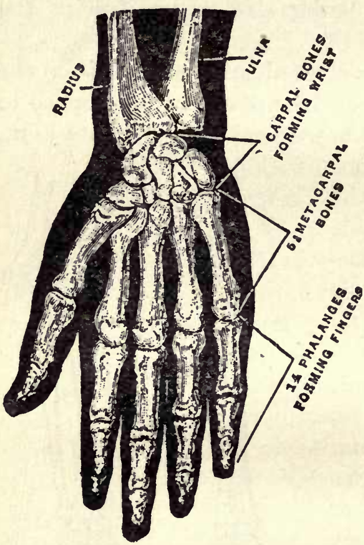

FIG. 20.—Bones of right hand.

21. The Bones of the Trunk.—The bones of the trunk are fifty-four in number: the VERTEBRÆ, or bones of the spinal column (Fig. 21); the RIBS; the STERNUM, or breast-bone; the HIP-BONES, the SACRUM, and the COCCYX. The spinal column is formed by the union of the several vertebræ. (Fig. 22.) These are divided into three groups, according to their positions. Those of the neck are known as the cervical, and are seven in number; those of the back as dorsal, and are twelve in number; and those in the small of the back or loins as the lumbar, and are five in number.

These bones vary somewhat in the different sections, though they have characteristics common to all; viz.: a cylindrical body, with the upper and lower surfaces somewhat hollowed; two transverse processes; two processes which project backward from the upper part of

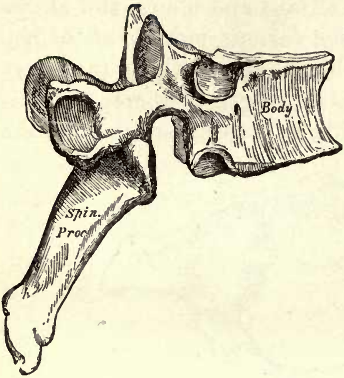

FIG. 21.—A dorsal vertebra, showing the body and the spinal processes.

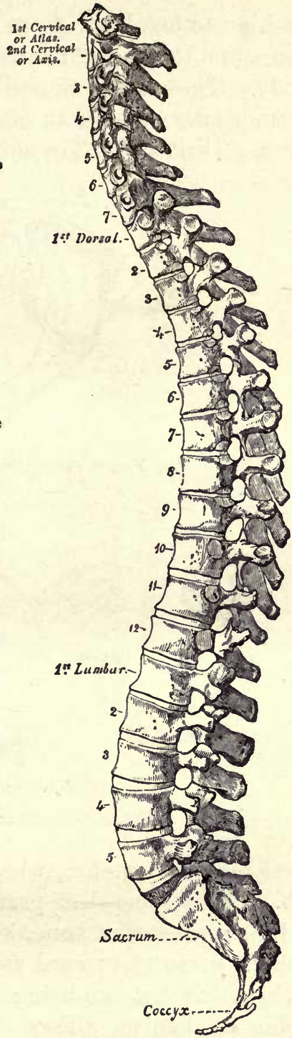

FIG. 22.—Side view of the spinal column, showing the cartilage between the vertebræ.

the posterior surface of the body and join in the median line to form the large opening, or foramen, through which passes the spinal cord; and a spine which begins at the point of union of the two processes and projects backward and downward. (Figs. 21 and 22.) The bodies of the cervical vertebræ are small; those of the dorsal are larger and the spine longer; while the lumbar are still heavier and stronger, with short, stout spines. (Fig. 22.) The bodies of the vertebræ are joined together by a substance known as fibro-cartilage, which acts as a

cushion to break the force of falls and blows, and allows the spine to bend during the various movements of the body. These pads, or cushions, are so thick that they form nearly one-fourth of the length of the spinal column. (Fig. 22.) The skull, or cranium, rests upon the

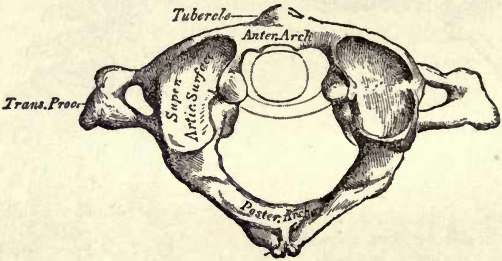

FIG. 23.—First cervical vertebra, or atlas.

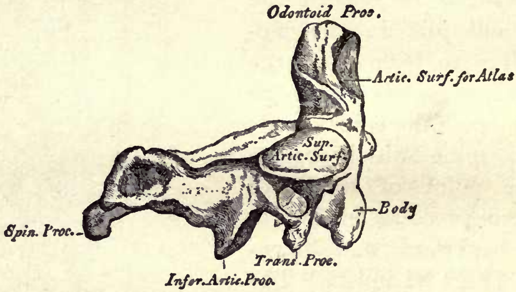

FIG. 24.—Second cervical vertebra, or axis.

first cervical vertebra, which is called the ATLAS. (Fig. 23.) It is somewhat peculiar, its body being split to admit a process of bone, known as the odontoid process, which projects upward from the body of the vertebra below, this vertebra being known as the axis. (Fig. 24.) This mechanism allows the head to turn freely from side to side. The last lumbar vertebra rests upon the sacrum.

The RIBS are twenty-four in number, twelve on each side, and are divided into true and false ribs. They are attached to the spinal column and extend forward and somewhat downward. The first seven pairs are attached to the sternum in front by prolongations known as the costal cartilages. Of the remaining five pairs three are attached to the costal cartilages, while the two remaining or lowest ribs have their anterior ends free and are known as floating ribs. (Fig. 25.)

The STERNUM, or breast-bone, completes the bony framework of the chest. It is long and flat and is shaped somewhat like an old-fashioned dagger. (Fig. 25.) The two CLAVICLES are attached to its upper end, and along its sides are seen the surfaces for the articulations of the costal cartilages which extend from the ribs to the sternum.

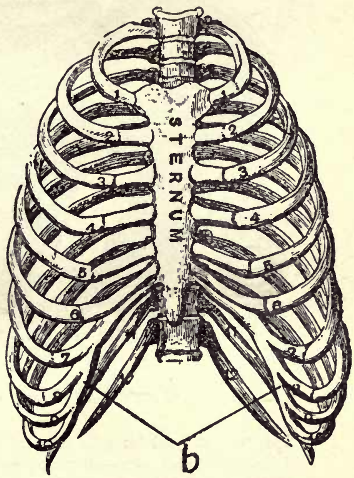

FIG. 25.—Showing ribs and sternum; *b*, costal cartilages.

The SACRUM is a large wedge-shaped bone held firmly by ligaments in its position between the two hip-bones. (Fig. 26.) In early life it represents five vertebræ, which later unite, forming a single bone, having on its posterior surface rough prominences which correspond to the spines of the vertebræ.

The COCCYX is a small bone attached to the lower end of the sacrum. It is curved from behind forward, and

receives its name from its fancied resemblance to a cuckoo's beak. (Fig. 26.)

The OS INNOMINATUM, or nameless bone, so called because of its resemblance to nothing in particular, is irregular in shape, and unites with the sacrum posteriorly and with its fellow anteriorly to form what is known as the pelvic girdle. Its outer surface presents a deep, cup-

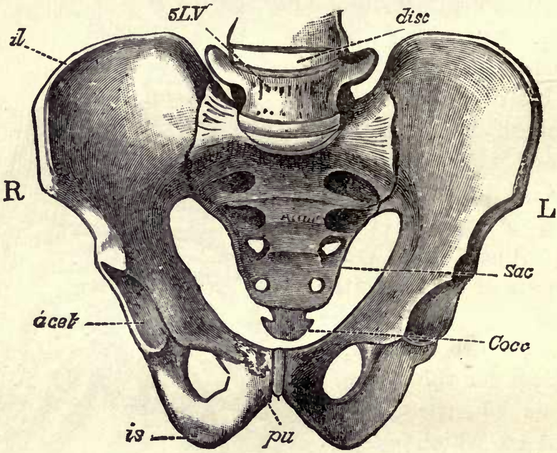

FIG. 26.—The pelvis: *sac.*, sacrum; *cocc.*, coccyx; *il.*, *is.*, *pu.*, ilium, ischium, and pubes—three parts of the innominatum; *acet.*, acetabulum, cup for head of femur; *5 l. v.*, 5th lumbar vertebra.

shaped cavity into which fits the rounded head of the thigh-bone, forming the hip-joint. (Fig. 30.)

22. The Bones of the Lower Extremity.—The bones of the lower extremity are thirty in number: the FEMUR, or thigh-bone; the TIBIA, or shin-bone; the FIBULA, or splint-bone; the PATELLA, or knee-pan; seven TARSAL, or ankle-bones; five METATARSAL BONES, and fourteen PHALANGES, or toe-bones.

The FEMUR is the longest bone in the body, and extends from the hip to the knee. (Fig. 27.) Its upper extremity is bent at an angle of about 45°, to form what is known as the head and neck of the femur. This neck is about 5 centimeters (2 inches) in length. Its end, enlarged and rounded, is known as the head, and fits into the cup-shaped depression on the outer surface of the hip-bone, forming the hip-joint. The lower end is enlarged, and shows two rounded surfaces for articulation with the tibia and patella. (Fig. 27.)

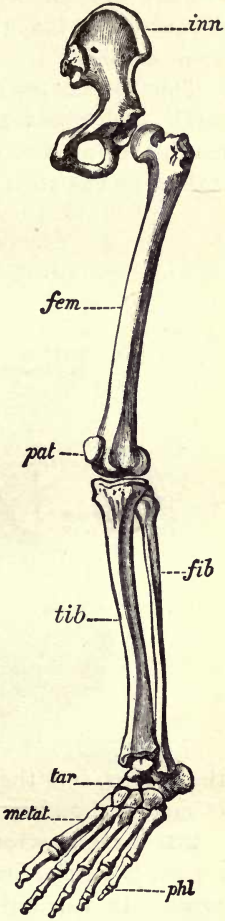

FIG. 27.—Innominatum and bones of lower limb. (See Fig. 33, and Table of Bones.)

The TIBIA corresponds to the ulna in the forearm. Its upper end forms, with the femur and patella, the knee-joint. (Fig. 27.)

The FIBULA is a long, slender bone on the outer side of the leg. Its upper end joins the tibia just below the knee-joint. Its lower end enters into the formation of the ankle-joint. (Fig. 27.)

The PATELLA is a small bone, somewhat triangular in shape, flattened from before backward. Its posterior surface is rough, for the attachment of the large tendons of the muscles of the thigh.

The TARSAL BONES correspond to the carpal or wrist-bones. The largest, known as the *os calcis*, projects backward to form the heel.

The next in prominence, the *astragalus*, unites with the tibia and fibula to form the ankle-joint. (Fig. 28.) They are all so bound together by ligaments and fibrous bands that there is very little movement of one upon another.

The METATARSAL BONES are the bones between the tarsal and phalangeal bones. Like the bones of the hand, they are five in number.

The PHALANGES of the toes correspond to those of

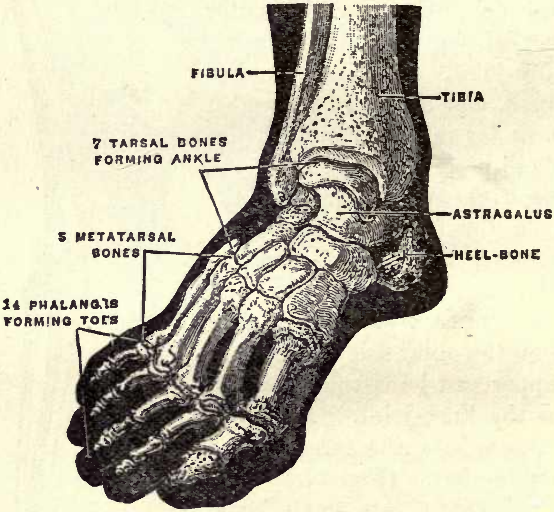

FIG. 28.—Bones of foot and ankle.

the fingers, but they are shorter and lack the freedom of motion found in the latter. (Fig. 28.)

23. Articulations.—When two or more bones unite, a joint is formed in which there is more or less movement. In the union of the bones of the skull the movement is very slight indeed, while in the shoulder or hip-joint we find the greatest freedom of motion.

In all the movable joints the articulating surfaces are

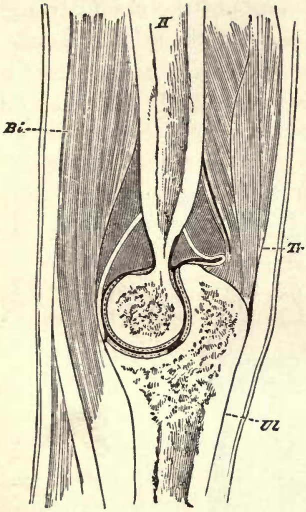

Fig. 29.—Section through elbow-joint. *H.*, humerus; *Ul.*, ulna; *Tr.*, triceps muscle; *Bi.*, biceps muscle.

found to be covered with a layer of smooth, elastic membrane, of a bluish-white color, called cartilage. This acts as a cushion to break the force of falls and blows, gives to the joints their smooth movement, and prevents nearly all friction.

Immovable joints are illustrated by the sutures; movable joints by the hinge-joint of the elbow

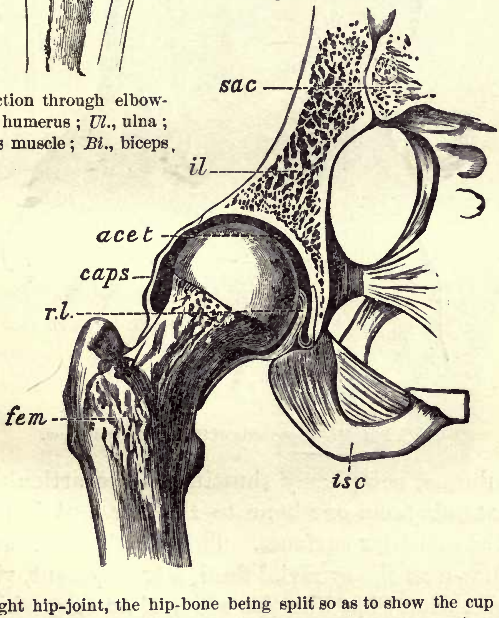

Fig. 30.—Right hip-joint, the hip-bone being split so as to show the cup of the joint: *fem.*, femur; *il.*, ilium; *isc.*, ischium; *sac.*, sacrum; *acet.*, acetabulum; *caps.*, capsule; *r. l.*, round ligaments.

(Fig. 29), the ball-and-socket joints of the shoulder and hip (Fig. 30), and the pivot joints of the atlas and axis.

24. Synovial Membrane.—Around each joint is found a thin, delicate membrane, called the synovial

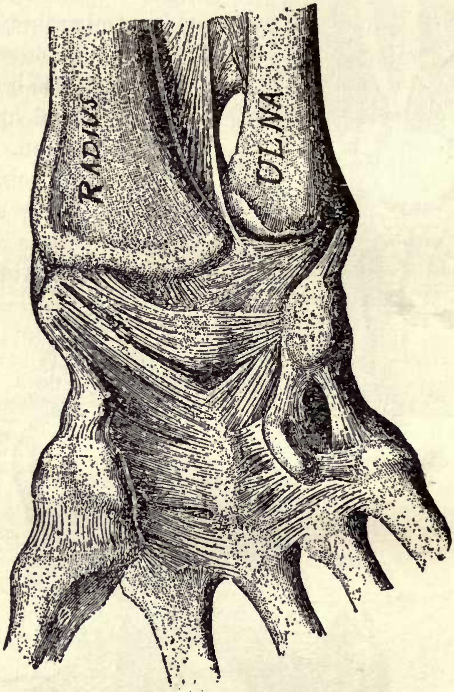

Fig. 31.—Ligaments of the wrist, front view.

membrane, completely shutting in the articular cavity. It extends from one bone to another, but is not found on the articular surfaces. This membrane secretes what is known as the synovial fluid, a transparent, viscid substance, somewhat like the white of an egg, which keeps the joint-surfaces moist and smooth.

25. Ligaments.—The bones entering into the formation of a joint are held in position by shining white bands of fibrous tissue called ligaments. (Fig. 31.) These ligaments are so arranged that they hold the bones firmly in position, while they allow freedom of motion in one or more directions. (Figs. 31 and 32.) They sometimes form a complete capsule, as in the hip-joint, allowing movement in any direction.

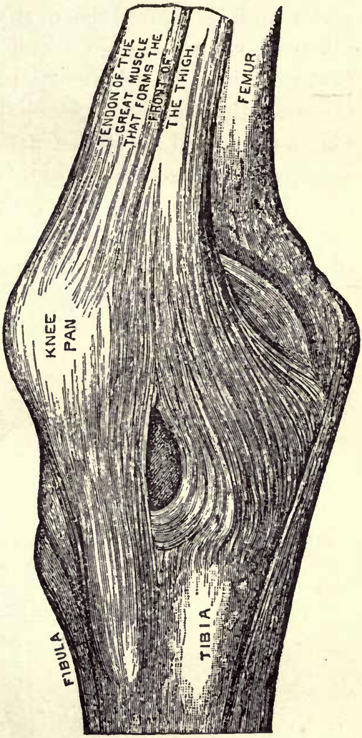

FIG. 32.—Ligaments of knee-joint.

26. Hygiene of the Bones—Alcohol.—At no time during life is dwarfing and deformity of the body so easily induced as during the period of growth. If the bones fail to grow, or grow out of shape, during childhood or youth, these defects can never be corrected. A fine, erect, well-developed figure is something to be desired.

In order that our bones may be strong and our bodies well formed, much care should be taken during childhood and youth, that our food be such as will produce strength and a healthy development. It should be plain and simple, and yet contain the materials that will build up tissue.

The clothing should be supported from the shoulders, and should not compress the ribs. Tight or high-heeled shoes should not be allowed to deform the feet. School-room desks should be adjusted to the size of pupils, so that the feet may rest upon the floor and a stooping position may be avoided. Correct positions of sitting and standing should be cultivated, and any system of physical culture should teach such positions among its first exercises. The use of stimulants of all kinds should be carefully avoided. Alcohol in all its various forms, tea, coffee, and all those articles which stimulate the appetite, are a source of evil in later years. Tobacco is one of the stimulants which produces great harm during the period of early youth. Cigarette smoking is to be decried at all times, but especially while the body is growing, and the bones getting form and substance.

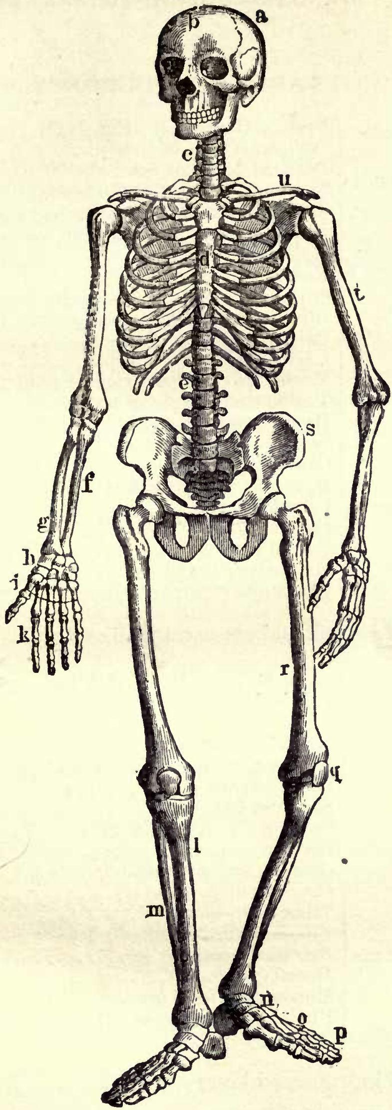

FIG. 33.—(See Table of Bones.)

TABLE OF THE BONES.

Skull.	Cranium	Frontal (forehead). Fig. 33 (*b*)	1	8	23
		Occipital (back of head)	1		
		Parietal (sides of head above) (*a*)	2		
		Temporal (sides of head below)	2		
		Sphenoid (at base of skull)	1		
		Ethmoid (base of skull over nose)	1		
	Face	Malar (cheek-bones)	2	14	
		Nasal (bridge of nose)	2		
		Superior maxillary (upper jaw)	2		
		Inferior maxillary (lower jaw)	1		
		Palatal (at back of nose)	2		
		Lachrymal (part of orbit)	2		
		Vomer (part of partition of nose)	1		
		Turbinated (inside of nose)	2		
		Hyoid bone (base of tongue)		1	
Upper Extremities.		Scapula (shoulder-blade)	1	32 in each arm.	64
		Clavicle (collar-bone) (*u*)	1		
		Humerus (upper arm) (*t*)	1		
		Ulna (*f*)...1, Radius (*g*).1 (forearm)	2		
		Carpal (wrist) (*h*)	8		
		Metacarpal (hand) (*i*)	5		
		Phalanges (thumb, 2; fingers, 3 each) (*k*)	14		
Total in skull and upper extremities					87
Bones of the Trunk.	Spine	Cervical vertebræ (*c*): Atlas, Axis, 5 others		7	24
		Dorsal vertebræ (supporting the ribs)		12	
		Lumbar vertebræ (in small of back) (*e*)		5	
		Ribs (12 each side)			24
		Sternum (*d*)			1
	Pelvic girdle	Sacrum	1		4
		Coccyx	1		
		Ossa innominata (hip-bones) (*s*)	2		
Lower Extremities.		Femur (thigh-bone) (*r*)	1	30 in each limb.	60
		Tibia (shin-bone) (*l*) ... 1, Fibula (splint-bone) (*m*) 1 (leg)	2		
		Patella (knee-pan) (*q*)	1		
		Tarsal (ankle) (*n*)	7		
		Metatarsal (foot) (*o*)	5		
		Phalanges (great toe, 2; other toes, 3 each) (*p*)	14		
Total in trunk and lower extremities					113
Total number of bones					200

QUESTIONS ON THE SKELETON.

1. What is the skeleton ? Mention some of its offices.
2. Why do the bones vary in shape and structure ?
3. What difference is there in the composition of the bones of children and of old people ?
4. How may the constituent parts of bone be separated ?
5. How are bones made at the same time strong and light ?
6. What is the periosteum ?
7. How is broken bone repaired ?
8. How are the bones of the skeleton usually classified ? What are the uses of the bones of the different classes ?
9. Describe the structure of the bones of the skull.
10. Name and locate the bones which form the cranium.
11. How are they joined together ?
12. What are the fontanelles ?
13. Name and locate the bones of the face.
14. How many, and what bones are included in the upper extremity ?
15. How many, and what are the bones of the trunk ?
16. Give a full description of the spine.
17. What other bones enter into the formation of the chest-cavity ?
18. What bones enter into the formation of the pelvic cavity ? Speak of their shape.
19. What and where is the hyoid bone ?
20. Name and classify the bones of the lower extremity.
21. What is a joint ?
22. Describe cartilage and explain its use.
23. What is the synovial membrane, and what is its use ?
24. How are the bones held in position at the joints ?
25. Name different kinds of joints.
26. What is the effect of poor or improper food upon the bones ?
27. What effect has the use of stimulants upon the bones ?

EXPERIMENTS ON THE BONES.

Note 1.—If the school is not supplied with a skeleton, bones of animals, secured from a butcher or marketman, may be used,

although the teacher should state clearly the difference between such and human bones.

Note 2.—It will frequently be found possible to secure separate bones of the human skeleton, or, perhaps, a complete skeleton, from some local physician, whose interest in the school and its work will thus be incited, and from whom valuable help and suggestions may be expected.

Note 3.—It will be found best, at first, to take only one or two bones into the classroom, and to allow all of the class to handle and carefully examine them; subsequently, more and more may be taken in until, finally, all of the bones are thus brought together, and the skeleton is "articulated" before the class. This process will be found of double advantage; first, it is a logical way of teaching; and, second, it will avoid all shock to the nerves of the most sensitive. No greater mistake can be made by the teacher, at the outset in the study of physiology, than to permit anything bordering on coarseness—either through the presence of specimens, or by word or action of pupil or teacher. It is a cruel thing to shock a sensitive nature. The greatest care should be taken that everything be scrupulously neat, and that the greatest delicacy always be observed in description and illustration. Everything of the spectacular and sensational should be rigidly excluded.

Experiment 1.—The size, shape, weight, color, hardness, strength, etc., etc., of different bones should be observed while in the hands of the pupils.

Experiment 2.—Study carefully the articular surfaces, the processes, uses, and location in the body, of the different bones.

Experiment 3.—After a careful study has been made, as indicated above, of the external appearance, etc., of a bone, its structure and internal appearance should receive attention; cutting (with a knife), sawing, boring, pounding, burning, should be tried by the pupils themselves, in order that they may learn in a practical and certain way many characteristics of bones.

Experiment 4.—Sections of bones of various forms and sizes should be made carefully by sawing, with a fine saw, across the bone at various places; also by splitting some of the longer ones. Note should be made of the difference in structure of the same bone in different parts; *e.g.*, the simple cavity in the shaft of a long bone, and the spongy appearance (cancellous tissue) near the enlarged extremities which articulate with other bones.

Experiment 5.—Too much emphasis cannot be placed upon a

minute study of the structure of bone. The microscope should be brought into use, and can best be made of practical help by the use of "slides," which now can be purchased at small cost.

That bone is composed of two distinct classes of substances—namely, animal and mineral—may be shown by the following familiar experiments 6, 7, and 8.

Experiment 6.—Soak a bone in a mixture of hydrochloric acid (one part) and water (six parts) until it becomes easily flexible, when it may be tied in a knot or twisted into any shape. The mineral portion has been removed by the action of the acid.

Experiment 7.—Carefully burn a large bone until it is found to crumble easily; although the shape is still preserved, the bone will be found to be much lighter, and so brittle that it may be easily broken into small pieces between the fingers. The animal portion has been removed by the action of the fire.

Experiment 8.—If now a portion of the thoroughly burned bone be immersed in the acid mixture, mentioned in (6) above, it will dissolve and disappear.

Having studied all of the characteristics of bones mentioned above, and as many more as the teacher is able to bring out, the pupil will be well prepared to begin a study of the bones, in their relations to one another.

Experiment 9.—Secure from a butcher or marketman a "joint" with as large a part of the two bones as can be handled conveniently; all of the flesh about the bones and the joint having been removed with a sharp knife, an opportunity will be afforded for a study of the periosteum.

Experiment 10.—The synovial membrane should be shown and studied as the joint is slowly laid open; the presence in the joint of a lubricating fluid, which is secreted by the synovial membrane, should be noted.

Experiment 11.—The "packing" of the joint should be noted and studied, as the cartilage covering the entire articular surface is revealed.

Experiment 12.—Different kinds of joints should be observed and studied; if the school does not possess a skeleton, the skull of some small animal can be obtained, in which the sutures may be studied; numerous examples of the hinge-joint, the most common of all, can be obtained easily; it is desirable to consider the attachments of muscles, and to study the bones as levers.

(Note.—The authors would recommend strongly that pupils be

encouraged to make separate drawings of many of the bones. This will be found to be of much interest to the pupils, and will act as a great stimulus to a department of work which too frequently becomes lifeless and formal; it will be found advantageous, as the work progresses, to encourage some of the most gifted with the pencil, or crayon, to make drawings in well-blended colors. It may also be found practicable to introduce modeling of certain parts, as the bones, the hand, the foot, etc., in clay, or putty, or, better perhaps, in paper pulp such as is now in common use for making "raised maps," etc. Afford opportunity for the play of genius, and no fear need be felt for the results.)

FIG. 34.—The muscles of the front of the body.

CHAPTER IV.

MUSCLES.

27. The Muscles.—The muscles constitute the fleshy parts of the body. Because of a peculiar quality inherent in the muscles, that of contractility, the bones of the skeleton are moved with a precision and dexterity truly wonderful. It is through this property of contractility that all the movements of our bodies are made. The skeleton is the mechanical contrivance that admits of rapid and dexterous movements, and the muscular system supplies the power which, under the control of the brain and nervous system, produces these complicated motions.

There are two kinds of muscles, voluntary and involuntary. The voluntary muscles are under the control of the will, and by means of them we move and act. The involuntary muscles act independently of the will, and perform their duty without thought or guidance on our part.

28. Structure.—The voluntary muscles are composed of little bundles of fibers, and each of these fibers is made up in turn of still smaller filaments, or strands, called fibrils. Each fibril has somewhat the appearance (under the microscope) of a string of beads. This appearance is due to fine transverse lines which divide the fibril into segments, and give to a collection of the fibrils, or a fiber, a striped or striated look, which gives the voluntary muscles the name of striped or striated muscular tissue. (Fig. 35.) The fibrils which compose

a muscular fiber are held together by a thin, transparent sheath known as the "sarcolemma."

The fibers are bound together by fine bands and filaments of connective tissue, and the whole muscle is encased in a sheath of strong but thin fibrous tissue known as the fascia. Because of this fascia the various muscles can be separated easily in dissecting, and the form is retained during the study of the several parts.

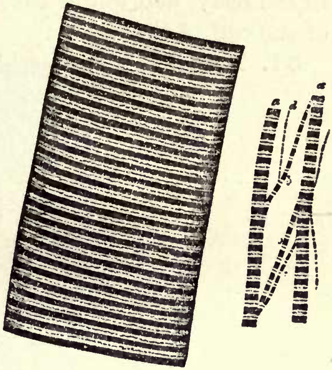

FIG. 35.—Voluntary muscular tissue.

29. Arrangement.—The muscles are usually found in sets or opposites. The large muscle on the front of the arm (Fig. 36), the biceps, is counteracted by the muscle on the posterior surface, the triceps. The one bends the forearm, the other extends the same. The fingers and toes have flexors and extensors, and wherever a joint is seen which has any degree of motion, there may be found a set of muscles which counteract each other.

30. Attachment.—Each muscle has an origin or head, a body, and an insertion. The origin is the most fixed part of the muscle, and usually arises from one or more of the bones. The body is the fleshy part in which contraction takes place. The insertion is the union of the muscle with the part to be acted upon during muscular contraction. This insertion is usually brought about by means of shining white bands or cords called tendons. The body of the muscle tapers and ends in strands of fibrous tissue, which unite and form these

tendons. They can be felt in the wrist and back of the hand. The tendon of Achilles (Fig. 37) is the largest in the body, and unites the heel with the large muscle of the calf of the leg.

31. Names.—The muscles of the body, of which there

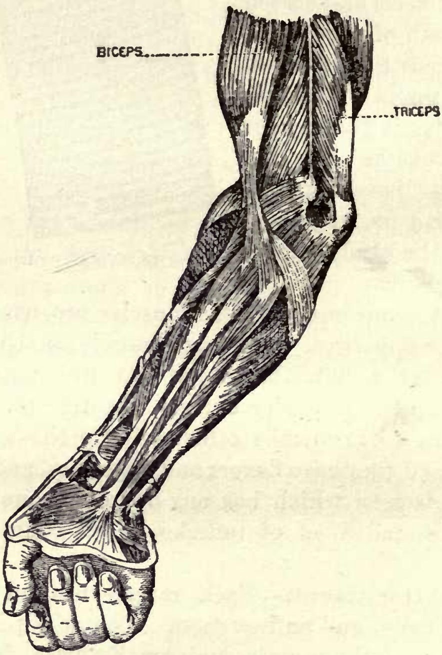

FIG. 36.—The muscles of the arm and forearm.

are about five hundred, derive their names from their size, as *magnus*, *minimus*, etc.; position, *superior* and *inferior;* attachment, *sterno-cleido mastoid;* action, *adductors* and *abductors;* and direction, *obliquus* and *rectus*. They are of shape and size according to their

situation, attachment, and the work they have to perform. The great muscle of the back may weigh several

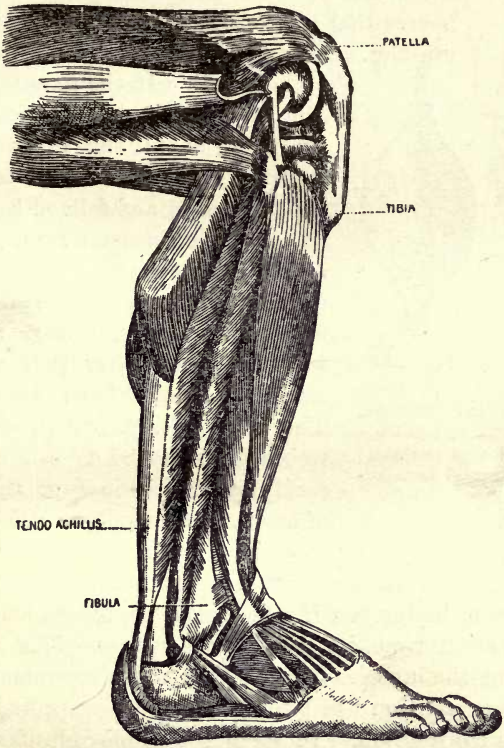

FIG. 37.—Muscles of the leg, knee, and foot, and the tendon of Achilles.

pounds, while the delicate muscle of the ear weighs hardly a grain.

32. Properties.—When muscular tissue is stimulated, or irritated, the phenomenon of contraction is observed. The body of the muscle increases in circum-

ference, it becomes harder to the touch, and its two ends approach each other. (Fig. 38.) This contraction occurs in the muscles of our bodies when the brain sends its message through the nerves that connect the motor center with the muscles. External violence also will produce a like result. If the muscle of the arm be struck a sharp, quick blow, the fibers about the injured part contract and a little knot or lump is plainly seen and felt. Electricity will produce the same result, and is used to exercise groups or sets of muscles which are paralyzed. Some muscles will respond to irritation for some time after they are entirely separated from the body. The heart of a frog will continue to beat if removed from the chest-cavity; and when it stops, the prick of a pin, or some slight mechanical irritation, may start it again. After a time it loses this property and will no longer respond. If it be allowed to rest, and, better yet, if it be bathed in blood, it regains, for a short time, its power to contract. The natural state of the muscles is relaxation, and they remain in a passive condition until some stimulus is applied which causes contraction. In sleep the whole voluntary muscular system is at rest, and repair of the damage done during the waking hours is constantly going on.

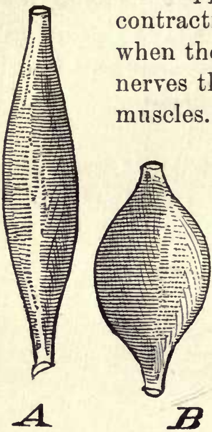

FIG. 38.—Showing change of form in a contracting muscle. *A*, muscle in the extended condition; *B*, the same muscle contracted.

33. Involuntary Muscular Tissue.—Involuntary muscular tissue is composed of elongated cells. (Fig. 39.) When this tissue is treated for some time, by immersing it in dilute acid, these cells may be separated, and appear as elongated objects, ten to fifteen times as

long as they are wide, with a rod-shaped nucleus, which is faintly visible near their centers. These cells are held together by a cement which binds them in position. This kind of muscular tissue is found in the hollow organs of the body, the intestines, stomach, bladder, etc. Organs in which this kind of muscular tissue is found do not contract quickly and regularly as do the striped muscles. The contraction begins slowly at a given point, and extends, while the part at first contracted becomes relaxed. It is this peculiar property which gives to the stomach and intestines their vermicular, or worm-like, movement.

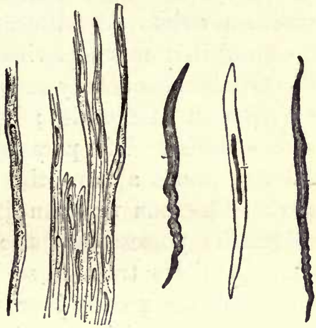

FIG. 39.—Involuntary muscular tissue.

34. Exercise.—With each contraction of a muscle a part of its substance is used up and becomes waste material. This waste material is carried away by the blood, and is replaced by new material, making the muscles as strong and firm as before. In order that the muscular system may be at its best, it is necessary for it to do a certain amount of work. If the amount of work be too little, the muscles lose their "tone" and become soft and flabby. Little particles of fat find their way among the fibers of the muscles, and a small amount of work is sufficient to give a sense of fatigue and weariness. If too much work be thrown upon the muscles, the process of waste goes on faster than that of repair, and the parts lose their form, decrease in size, and perform their work less easily, because of diminished vitality. If a set of muscles be duly exercised each day, they increase in

size, become firmer, and can perform more work before the feeling of fatigue is experienced. This is well illustrated by the blacksmith's hammer-arm. It is larger and firmer than its fellow, and at the end of a day at the anvil it is not more tired than the rest of his body. The whole muscular system may be trained as readily as a single set of muscles; hence the beneficial effects of daily exercise. The person who takes the most vigorous exercise is not always the one who acquires the most good. The man who can lift the heaviest weight is not necessarily possessed of the best-trained muscular system. Athletes train in such a way that their powers of endurance are greatly increased, and do not necessarily aim at feats requiring great physical strength. A muscle that can raise a hundred-pound dumb-bell without great fatigue might experience the greatest difficulty in raising a two-pound dumb-bell fifty times in quick succession, if not trained to endurance. It is the power to endure continued exertion that indicates the most perfect physical training. It is not necessary or advisable that every one should become a trained athlete, but for his general welfare each person should take a certain amount of physical exercise daily. Then the muscles are in condition to meet any necessary strain that may be put upon them, the heart is enabled to do extra work without overtaxing it, and the whole economy is so balanced that waste and repair are equalized, each organ performing its function with precision and regularity. "That exercise is deficient which does not engage the vigorous action of the chief muscles of the system for a considerable period each day; and that too great which, passing beyond the point of simple fatigue, is prolonged to the period of exhaustion."— Wm. Jay Youmans, M.D.

35. Kinds of Exercise.—One of the best and simplest kinds of exercise is walking. Nearly all the

muscles are brought into action, the heart's action is slightly accelerated, and the lungs are filled and emptied with greater frequency. Running, jumping, bicycling, fencing, and boxing are all excellent exercises and have the advantage of the open air. Gymnasium-work is better calculated to develop certain sets of muscles that are weak and lack tone and firmness. Practice of this kind is exceedingly beneficial, and the muscular system can be systematically developed, and the general condition greatly improved; but it lacks the outdoor air, which is one of the beneficial accessories of exercise in general.

36. Time for Exercise.—Violent exercise should be avoided at all times, but more especially directly after meals. At this time large quantities of blood are being carried to the stomach and intestines to aid in supplying the digestive secretions. Any exercise which draws the blood away from the digestive organs, to aid in repairing the waste which occurs during muscular exertion, impairs digestion. The best time for exercising is about two hours after eating, but no exact time can be set for this physical training. Gentle exercise is never harmful during health, unless it be directly after a full meal. "Violent physical exercise taken early in the morning is very exhaustive, . . . and probably in most instances the student has cultivated nervous dyspepsia quite as much as he has cultivated his muscles. 'Every pound of energy expended on work, either of mind or of body,' says Dr. Sargent, 'must be made good by food, rest, or sleep.'"—W. T. Harris, LL.D., U. S. Commissioner of Education.

37. Effects of Alcohol.—The effects of alcohol on the muscular system are perhaps more directly apparent than upon the other organs of the body. A person under the influence of alcohol loses control of the mus-

cles of the body; the walk becomes unsteady, for the muscles do not act together; there is inability to perform work that is at all delicate. The small muscles that act upon the eye do not work in concert, and double vision results; the same is true of the muscles which control the organs of speech, and the speech becomes thickened and indistinct.

If enough alcohol be taken, the whole voluntary muscular system finally refuses to act, and the person becomes helpless.

It is supposed, by many people, that more work can be done if they take a certain amount of alcohol to spur them on, but this idea is fast losing ground. It has been shown conclusively that alcohol does not increase muscular activity, nor add to the strength of the system. It does not increase the power of endurance, nor aid in withstanding great heat or extreme cold. Soldiers who are not served with "grog" will march farther, fight better, and endure greater hardships than their stimulated companions. The feeling of exhilaration and renewed strength is deceptive, for experience shows the increase in ability, in whatever line of work, is only an imaginary one. Persons who have used alcohol in large quantities for a long time find themselves unable to perform delicate kinds of work. The hand becomes unsteady, there is muscular trembling, and the skill and dexterity they once possessed gradually leave them. Their power of endurance is greatly reduced, and the muscles are soft and tire easily. The microscope shows little globules of fat within the sarcolemma of the muscular fibers. These deposits of fat take the place of muscular tissue, and give the muscles a bloated appearance. They destroy the contractility to a great extent, and so reduce the power of endurance that physical labor is almost impossible.

"Workingmen who abstain from intoxicating drinks show a better health, a longer life, and a better capability of resisting disease and the results of accident."—J. J. Ridge, M.D., B.S., B.A.

"It is the diminution of nerve sensibility that renders the individual at first light, airy, and hilarious, giving the popular idea of excitement or stimulation; second, dull, hesitating, or incoherent in thought or speech, and unsteady or swaggering in gait, a stage popularly recognized as incipient intoxication; and third, brings on entire unconsciousness and muscular paralysis, constituting dead drunkenness or complete anæsthesia. These successive stages are developed in direct ratio to the quantity taken."—Dr. N. S. Davis, A.M., LL.D., Dean of the Northwestern University Medical School, and President of the American Medical Association.

"Labor of the severest kind, mental and bodily, can be carried on without them (intoxicating drinks), and the steadiest and best work done."—B. W. Richardson, A.M., M.D., LL.D., F.R.S.

QUESTIONS ON THE MUSCLES.

1. What do the muscles constitute?
2. What peculiar quality have the muscles?
3. Of what use is this quality?
4. What are the mutual relations of the skeleton and the muscles?
5. Classify the muscles.
6. What is the office of each kind?
7. Describe the structure of the voluntary muscles.
8. What is the sarcolemma?
9. How are the fibers bound together?
10. What is the fascia?
11. Describe the arrangement of the muscles.

12. Name two of the most important muscles of the arm, and describe their action.
13. What may always be found about a joint?
14. Name and describe the different parts of a muscle.
15. What are tendons? Name and describe the largest tendon.
16. How many muscles are there, and according to what plan are they named?
17. What determines the shape and size of the muscles?
18. Describe muscular contraction, and mention some of its causes.
19. What is the natural state of the muscles?
20. Describe the involuntary muscular tissue. Where found?
21. What causes the vermicular movement?
22. How is the waste and repair of muscular tissue carried on?
23. What is the effect of too little, and of too much work upon the muscles?
24. What is the effect of gentle daily exercise upon a set of muscles? Illustrate.
25. What is the most perfect physical training? Illustrate.
26. Why is daily physical exercise a necessity?
27. How much should be taken?
28. What are the best kinds of exercise?
29. What is the value of gymnasium-practice?
30. What is the best time for exercise? Why?
31. What are the immediate effects of alcohol upon the muscular system?
32. How does alcohol affect muscular activity, strength, and power of endurance?
33. What is the effect upon the muscular system of the continued use of alcohol?

EXPERIMENTS ON THE MUSCLES.

1. By means of boiled lean meat, the muscles themselves and also the sarcolemma and fascia may be studied.

2. The fibers and fibrils may be studied by means of boiled corned beef, and the fibrils should be shown under the microscope.

3. The tendons may be seen in the back and wrist of a thin hand, and may be taken from the leg of a fowl.

4. The muscles of the thumb and the biceps afford good illustrations of muscular contraction.

5. Study the arm, the foot, etc., as levers.

6. Layers of muscles devoid of sarcolemma may be seen in a heart.

7. Involuntary muscular tissue may be found in the middle coat of the arteries, but cannot be studied without a powerful microscope.

CHAPTER V.

FOOD AND DRINK.

38. If our bodies be examined chemically, each part of the organism is found to be made up of definite chemical compounds. The bones, the muscles, connective tissue, etc., are composed of the elements found round about us. As the compounds of nature are constantly changing, so are the tissues of the body continually taking on and throwing off material. We take into our bodies substances called food, and this food is broken up into compounds which can be taken into all parts of the system by the blood. During their journey through the blood-vessels these compounds are taken up by the various tissues and become a part of the living organism. The blood, after it has given up its supply of building material, is found to contain certain waste products given off by the tissues, which are constantly undergoing changes. These waste products are hurried along by the blood-current to the organs of excretion, to be thrown off from the body.

39. Waste and Repair.—This process is known as waste and repair, and it is going on constantly. During waking and sleeping, the system is rebuilding the tissues used up in maintaining the heat of the body, or destroyed during muscular activity. With each movement, with each physiological process, with each thought, there is a waste of tissue which corresponds to the severity of the work done, and to keep the body in a healthy condition these waste products must be disposed of, and the damaged tissues restored to a normal condition.

40. Food.—The different foods may be studied best by dividing them into four classes:

I. INORGANIC OR MINERAL FOODS.

II. ALBUMINOUS OR NITROGENOUS FOODS.

III. FATS AND OILS.

IV. STARCHES AND SUGARS.

41. Mineral Foods.—The mineral substances that enter into the formation of the body are the compounds of sodium, potassium, magnesium, and lime, with chlorin, phosphorus, sulphur, and carbon. The phosphate of lime enters largely into the composition of bone, and sodium chlorid is found in nearly every tissue and fluid of the body. The other compounds are associated with these, in a greater or less degree, in the various parts of the system.

These substances are taken into the body with the food-stuffs of which they are a part, and are combined with the tissues of the body, and, finally, are thrown off in the processes of waste and repair, without having undergone chemical change during their stay in the system. Iron is also found in the body, but in smaller quantities than the other compounds. Traces of other minerals are also present, but those mentioned are the most important.

42. The Albuminous or Nitrogenous Foods.—The albuminous or nitrogenous foods, of which the white of egg is the purest type, form a large part of all meats, and enter into the composition of the various grains or cereals. The several kinds of albumin differ from other foods in containing nitrogen, while carbon, oxygen, and hydrogen only are found in the others. They change their consistency on the application of heat or the addition of an acid, as when an egg is fried or boiled, or milk is coagulated in making cheese.

They undergo "catalytic transformation;" that is,

a change is produced in their composition by the presence of a substance known as a *ferment*. This acts in an unknown way. It does not seem to enter into the composition of the new substance, or to diminish its quantity, yet it starts the catalytic process by its presence. After this change has taken place in an albuminoid substance the product is known as a peptone. The albumins are subject to decomposition. When animal tissue is exposed to the atmosphere it breaks down, liquefies, gives off offensive gases, and finally disappears. This process is known as *decomposition*.

Pease and beans, and other plants of the pod family, are rich in albumin. It is also found in wheat, barley, oats, etc. Because of its presence in the grains and vegetables, we are able to subsist on a purely vegetable diet. Cow's milk contains 43 parts of albumin in 1,000. It is almost a perfect food, supplying all the substances necessary for the maintenance of life. It curdles, or becomes a semi-solid, if left exposed to the air. Electrical changes in the atmosphere also produce like results. This is due to the formation of an acid from the ingredients of the milk. The presence of an acid like that contained in the stomach will quickly cause this change; hence milk is not the fluid food it seems, but a semi-solid, which needs to be digested.

43. The Fats and Oils.—The fats and oils are largely of vegetable origin. Most of the grains, fruits, and nuts contain fats and oils, and from these the oleaginous portion of our food is derived. The fatty part of meat, of eggs, and of milk, which constitutes so large a part of our diet, is derived from grains and vegetable growths consumed by the lower animals. Fats are also formed from the starches and sugars in the chemistry of the body, as well as in the chemistry of the plant; for

persons who are inclined to be portly grow fat on starch and sugar.

44. Emulsification.—If oil be thoroughly beaten or shaken in a watery solution of the white of egg or mucilage, the menstruum turns white or milk-like, and remains so. The oil is broken up into minute globules, and a thin coating of albumin or mucilage is formed around each particle, keeping it separate from its fellows. This is called emulsification.

Fats may also be *saponified* by boiling in an alkaline solution. During this process a change takes place in the chemical composition of the fats. They are broken up into fatty acids and glycerin, and the acids unite with the alkali to form more stable compounds.

45. Starches and Sugars.—Starch is found in abundance in all the grains and fruits. Rice, sago, arrow-root, tapioca, etc., are nearly all starch. Roots of the tuber family, as the potato and beet, contain a large percentage of starch; and, generally speaking, it is taken into the system in larger quantities than any other food. Sugars, of which there are several varieties, are formed from the starches by the addition of one part of water to each part of starch: $C_6H_{10}O_5$ (Starch) + H_2O (Water) = $C_6H_{12}O_6$ (Sugar). The sugar of ripe fruit is the starch of the unripe fruit brought into chemical combination with water by the heat of the sun and by moisture. Starch forms a large part of our food; but it is insoluble, and before it can be used in the chemistry of the body it is changed to a sugar, which is freely soluble, and can be carried by the blood to all parts of the body. This change occurs during digestion.

46. The Kind and Amount.—The kind and amount of food which we consume depend largely upon our likes and dislikes, mode of living, occupation, and circum-

stances. Bread is so universal a food that it is often spoken of as the "staff of life." It contains so many of the food-essentials that it will sustain life almost as well as the large variety of materials which compose our diet-list. People who perform manual labor, or take a great deal of exercise, require more of the flesh-producing foods, as meat, milk, and eggs ; though starchy foods are by no means to be discarded. The appetite is the best guide in selecting our food, for we crave the things the system requires, unless the appetite is perverted by the use of highly seasoned food, condiments, or the liquors which contain alcohol. A simple, wholesome diet, containing meat, vegetables, and breadstuffs, is best calculated to keep the system in condition to meet the requirements of everyday life.

47. Cooking.—In order that our food may be more palatable, more readily masticated, and more easily digested, it is made to undergo a process of baking, boiling, or frying. During this process the various forms of albumin are coagulated ; bundles of muscular fiber are partially broken to pieces ; and the starches, by the aid of heat and moisture, are partially turned to sugar. When meats are baked, or boiled, the heat at first should be great. In this way an outer crust, or layer, of coagulated albumin is quickly formed, and the juices and flavors of the meat are retained beneath this covering. The heat may be reduced after a little, and the cooking allowed to go on at a slower rate. When a soup, or a stew, is to be made, the temperature at the beginning of the process should be low, so that the water may penetrate the meat and its flavor and juice be thoroughly extracted. The art of cooking is a masterly one, and requires a large amount of experience. A good cook follows the laws of chemistry and physiology to a remarkable extent, though it may be unconsciously ;

experience develops a practical knowledge of these laws, though they may not be understood.

48. Drink.—There is no article of diet of greater importance than the water which we drink. It is more liable to be contaminated than the solid foods, and, because of its solvent properties, more likely to contain impurities. Water enters into the formation of all vegetables, and many of the mineral substances. Our bodies are nearly three-fourths water, either in chemical combination, or in a free state. It is taken into the system in large quantities in our food and as drink, and is excreted, holding in solution various substances which act as poisons if retained in the body. The blood is composed largely of water, and it holds in solution the products of digestion, and carries to each part of the body materials for keeping the various organs in a healthy condition. Water gives consistency to all the tissues of the body, allows the muscles to contract, and gives elasticity to the bones. It is of so much importance as an article of diet, that life can be sustained longer upon it alone than upon solid food without it.

49. Sources.—Water comes from two sources—from the sky, where it floats in the form of clouds and mist, and from the ground. Rain-water is the purest form of natural water, for it contains no impurities, as it falls, except such as may be floating in the air, as dust, smoke, the pollen of plants, etc. These are of little moment, as they are readily removed by filtering. When water from this source is used, the receptacles, as tanks and cisterns, should be kept clean, and should be in a place where they are not likely to become contaminated. Water from the ground may be obtained from springs, wells, running streams, or reservoirs. It contains more or less of the impurities of the soil through which it percolates, and is liable to contamination from

decaying vegetables and mineral matter. Large cities frequently have their water-supplies contaminated, and epidemics, more or less severe, follow. Some spring-waters are highly charged with carbon dioxid, which imparts a sparkle to the water and gives it a pleasant taste. Many spring-waters hold in solution ingredients which give them medicinal properties, and they are used largely as medicines. Water which is perfectly clear and pleasant to the taste may be contaminated with disease-germs, and contain impurities which make it unsafe to use for drinking purposes. If water be suspected, it should be boiled before it is drunk. A little fruit-juice of some kind may be added to improve the taste. Drinks which are iced should be taken with some degree of caution. However palatable they may be, they are liable to do harm, if taken in large quantities when the body is heated, or during digestion. When taken, they should be drunk slowly, lest the sudden cold produce ill effects upon the system.

50. Tea, Coffee, and Chocolate.—Tea, coffee, and chocolate are beverages in constant use. They have become articles of necessity rather than of luxury, and are harmless, unless taken in too large quantities. Indeed, they are often beneficial, and enable the system to endure hardships it would otherwise be unable to sustain. The active principle in each is used in medicine, and the physiological action has been carefully studied, and is well understood. Their active principles act in such a way on the tissues of the body that the changes which are constantly going on are held in check, and more work can be done on the same amount of food. Harm from these articles comes, not from their use, but from their abuse.

CHAPTER VI.

ALCOHOLIC BEVERAGES.

51. Besides the articles of drink already mentioned, there is another class of liquids so commonly used and so deleterious in its effects as to require special mention.

These beverages all contain alcohol in varying quantities, the effects of which, if taken regularly and in sufficient quantities, are such that the whole system suffers.

Their constant use promotes indolence, leads to vicious habits, blunts the sensibilities, and lowers men and women to the depths of mental and moral degradation.

52. Fermentation.—Fermentation is the process by which much of the animal and vegetable matter around us is changed into entirely new compounds. Meat putrefies, milk sours, bread molds, and the juices of various fruits work. A tree falls in the forest and decays, the leaves of plants turn brown and finally crumble to earth. All these changes are due to different forms of fermentation, and heat and moisture are the two essentials which permit of these processes.

Germs of fermentation are everywhere present, and, with a sufficient amount of heat and moisture, the process of fermentation is active in producing changes in nature.

When proteid matter decays, offensive gases are given off, and the process is called putrefactive fermentation.

The process by which wine and cider are changed to vinegar is known as acetous fermentation.

When alcohol is a product of fermentative changes the process is vinous fermentation.

Lactic fermentation takes place in milk, and saccharine fermentation in germinating seeds.

Fermentation changes completely the character of any substance upon which it works.

It is caused by the growth of microscopic fungous plants known as ferments, or yeasts.

53. Ferments, or Yeasts.—Pasteur says: "These infinitely small organisms are the masters of the world. If we could suppress their work, which is always going on, the surface of the globe would soon become uninhabitable."

The germs which cause vinous fermentation have been studied and their mode of operation closely watched, yet the way in which the changes in compounds are produced is but partially understood.

These germs appear, under the microscope, as small bead-shaped cells, and, under favorable circumstances, multiply very rapidly by the "budding" process, as it is called.

They double and treble in numbers very quickly, and are most active in producing vinous fermentation.

When some of these cells, in the form of yeast, are introduced into a solution of sugar, and the solution is kept at a moderately warm temperature, vinous fermentation very soon begins.

Minute bubbles form, rise to the surface, and pass off as carbon dioxid, and the other elements which formed the sugar unite to form alcohol, which remains in the solution.

This process is taken advantage of by manufacturers, and the various wines and malt beverages are the result.

54. Wines.—Wines are made by allowing the juices of the various plants, especially the grape, to ferment.

The fruit is crushed and the juice extracted by pressing. It is not necessary to add ferment-germs to the juice to start the process of fermentation, for they are always present on the skins, in the "bloom" of the fruit before it undergoes crushing.

There is considerable sugar in the juices of the various fruits, and when fermentation begins it is converted into carbon dioxid and alcohol.

After the process has reached a certain point, the alcohol, curiously enough, stops the action of the ferment.

The germs are destroyed by the presence of their own product.

If the quantity of sugar present is large, the alcohol will accumulate until it reaches sixteen or eighteen per cent.; then the process stops. If sugar still remains, the wine has a sweet taste, and is said to be a "sweet" wine. If all the sugar is used up, the wine is sour, and is called a "dry" wine. The amount of alcohol, varying from eight to twelve per cent., is much smaller in the dry wines than in the sweet wines.

Cider is the fermented juice of apples. Perry is made from the juice of pears.

Various small fruits are used to make wines, such as the currant, raspberry, blackberry, and elderberry. They are sweet wines and have quite a large percentage of alcohol.

The home-made beers, such as lemon, birch, honey, and root, all contain one or two per cent. of alcohol.

55. Malt Beverages.—Malt beverages—lager beer, ale, porter, and stout—are produced by fermenting the sugar obtained from the cereals ; usually barley, though sometimes wheat, rice, or corn, is used.

The grain is put in a warm, moist place until the kernels begin to sprout. By this process the starch,

which constitutes a large part of the kernel, is turned into a form of sugar known as maltose. The sprouting grain is then dried and charred to prevent the process from going farther.

This product is called malt, and contains the sugar or maltose formed from the starch in the grain, and other soluble matters. The malt is mixed with water and the soluble matter dissolved. This is called the wort. It is drawn off and boiled with hops to give it a bitter taste, and also to destroy any germs that may be present in the solution.

Yeast is then added to the wort, and fermentation is allowed to go on until alcohol is present in amount varying from two to ten per cent.

The liquor is then drawn off and kept in a cool place.

The dark color of ale and porter is due to the charring of the sprouting grain, it being carried farther than when lager beer is to be the product.

56. Distilled Liquors.—Besides the wines and malt beverages there is still another class of liquors very much stronger in alcohol.

These are the distilled liquors—whisky, brandy, gin, and rum. They are obtained by the process of distillation.

The distiller takes the wine or wort after it has been fermented, and heats it in a retort called a still.

The steam which rises from the surface is conducted through a long coil of pipe, called the worm of the still, which is kept cool by being immersed in water.

In the worm the alcoholic vapor, together with other volatile substances which impart a flavor to the liquor, is condensed and caught in vessels for that purpose.

Whisky is made from rye, corn, potatoes, etc.

Brandy is distilled from wine or the fermented juice of some fruit.

Gin is twice distilled, and flavored with juniper berries.

Rum is obtained by distilling fermented molasses or the juice of the sugar-cane.

These liquors contain from forty to sixty per cent. of alcohol.

This high percentage of alcohol can be obtained by distillation, because alcohol boils at a much lower temperature than the water with which it is mixed.

57. Pure Alcohol.—By redistilling and clarifying, almost pure alcohol can be obtained. It is a clear, colorless liquid, with an acrid, pungent taste, lighter than water, and burning with a pale blue flame.

It is used in the arts and sciences as a solvent and as a reagent, and is a most valuable product to the chemist and scientist. Alcohol is a narcotic poison, belonging to the same class as opium and chloral. One great peculiarity of these poisons is that their use, even in small quantities, creates a morbid appetite for more.

58. The Alcoholic Appetite.—The use of alcoholic beverages for any length of time affects the system in such a way that an unnatural craving for alcohol is excited. The oftener this craving is indulged the stronger it becomes, until it finally obtains complete mastery of its victim.

It is not the taste of the liquor that is desired, for this is oftentimes disagreeable ; it is its after-effects.

When the alcoholic appetite becomes so strong that it is uncontrollable, a person will resort to almost any device to obtain drink.

All sorts of hot, pungent substances, such as ginger, red pepper, and pain-killer are resorted to, to allay the craving. A person with such an abnormal appetite is looked upon as diseased in both body and mind, and there are many institutions throughout the land where the treatment of the "drink-habit" is given special attention.

The sure way to avoid this vicious habit is to refrain entirely from using, as a beverage, any liquor containing alcohol.

Beer and wine do not contain a large amount of alcohol, but, as the use of a little is liable to create an appetite which demands more and more, their use is a menace to health and character.

"It will be found by all who will investigate the subject that alcoholic drinks are not articles of food; that they never serve as food; do not behave in the body as foods do; they are always rejected and thrown out of the body as soon as they can be got rid of by the organs which scavenge the blood and keep from it impure and poisonous matter."—Dr. James Edmunds, of the London Hospital.

"Alcohol, like other substances of a narcotic nature, has the power when taken frequently, even in small quantities, to create a diseased appetite for more, which may become uncontrollable, and its gratification destructive."

(The above statement was signed, in 1896, by thirty-five eminent physicians of the United States, as a formula to be taught children and youth, in our public schools.)

QUESTIONS ON FOOD AND DRINK.

1. What is food ?
2. What, besides building material, does the blood contain ?
3. What is meant by waste and repair ?
4. How may foods be classified ?
5. Mention the mineral substances that enter into the formation of the body.
6. How do these substances become a part of the body ?
7. What are the albuminous or nitrogenous foods ?
8. How do they differ from the other foods ?
9. What is a peptone ?

10. What is decomposition ?
11. What can you say of milk as a food ?
12. How are fats and oils obtained ?
13. What is emulsification ?
14. How may fats be saponified ?
15. Where is starch found ?
16. How is sugar formed ?
17. What can you say of bread as food ?
18. What is the best guide in selecting food ?
19. What is the purpose of cooking ?
20. What difference should be made in cooking meat for a soup and for a roast ?
21. Of what importance to the body is water ?
22. What are the sources of water ?
23. How may contaminated water be made fit for use ?
24. What can you say of the use and abuse of tea, coffee, and chocolate ?
25. What is fermentation ?
26. Name some of the kinds.
27. What are yeasts ?
28. How is alcohol produced by fermentation ?
29. What is the difference between wines and malt liquors ?
30. How are distilled liquors obtained ?
31. Of what use is alcohol ?
32. What effect on the system have alcoholic beverages ?
33. Why are beer and wine harmful ?
34. Has alcohol any food-value ?

EXPERIMENTS ON FOOD AND DRINK.

1. Examples of food under each of the four classes may be collected in small glass bottles. Encourage the pupils to bring samples of all common foods, and classify them.

Under mineral foods, compounds of lime may be illustrated by burned bones, egg-shells, and shells of mollusks. Sulphur is contained in eggs, and blackens silver used in eating them. Various kinds of salts may be obtained from a druggist.

2. Teach that nitrogenous foods contain one or more of the organic substances—albumin, casein, fibrin, gelatin, and gluten.

White of egg is nearly pure albumin. The curd of milk is the best example of animal casein. Pour a little vinegar into milk,

heat the compound, and squeeze the curd from the whey. (At the same time the perfection of milk as a food may be shown. The cream furnishes fat; the curd, albumin; the whey, sugar dissolved with minerals in water.)

Legumin is another name for vegetable casein. It may be obtained by boiling a few peas or beans for a long time, until they become a sticky mass.

Fibrin may be seen in a clot of blood. It may be obtained by washing and squeezing a bit of lean meat. If a bowl of fresh blood be whipped with a bunch of twigs, and the twigs be dried and then washed, the fibrin will be found in the water, and clinging to the twigs.

Prepared forms of gelatin may be shown, or a bone may be boiled and gelatin obtained directly. The coarsest form of gelatin, from hoofs, is glue; the finer, from skin, is size; and the finest, from air-bladders and membranes of fish, is isinglass.

Gluten may be obtained by chewing some grains of wheat, or by squeezing a handful of wheat-flour in a bit of muslin in a basin of water. The starch will be washed from the flour, and the sticky substance remaining is gluten.

3. Show examples of oils expressed from nuts and fruits, from cocoanuts and orange-skins, for example. Exhibit specimens of animal oils and fats. Make an emulsion by shaking some oil in a mixture of white of egg and water. Make soap by boiling fat in a solution of potash.

4. Show under the microscope various forms of starch-granules.

5. Make a collection of different kinds of sugar; as, for instance, sugar of milk, cane, maple, grape, and beet sugar.

CHAPTER VII.

DIGESTION.

59. The Alimentary Canal.—The alimentary canal is that part of the body in which the food taken into the system is masticated, digested, and absorbed into the circulation. It consists of a hollow muscular tube, about 9 meters (30 feet) in length, with enlargements or cavities, in which the various kinds of foods are brought in contact with digestive ferments, which change their composition and make them ready for absorption and assimilation. (Fig. 40.)

The whole canal is lined with a layer of soft mucous membrane containing glands which secrete the mucus and the digestive fluids, which produce the various changes in the food and aid the passage of digested and effete matter along the length of the digestive tract.

The changes produced in digestion are often extremely complex, and are but partially understood. It is very difficult to trace a given substance through the length of the digestive apparatus, and to note the changes produced, but physiological chemistry has brought to light much that, for years, was obscure or not understood at all.

60. Mastication.—The food, when taken into the mouth, is ground into small pieces between the surfaces of the teeth. This enables the digestive fluids to act upon each particle of food much sooner, and more effectively, than if these substances had been swallowed in lumps. It is a purely mechanical process, yet it

serves to mix the secretions of the mouth with the food, making a soft, pulpy mass which is easily swallowed.

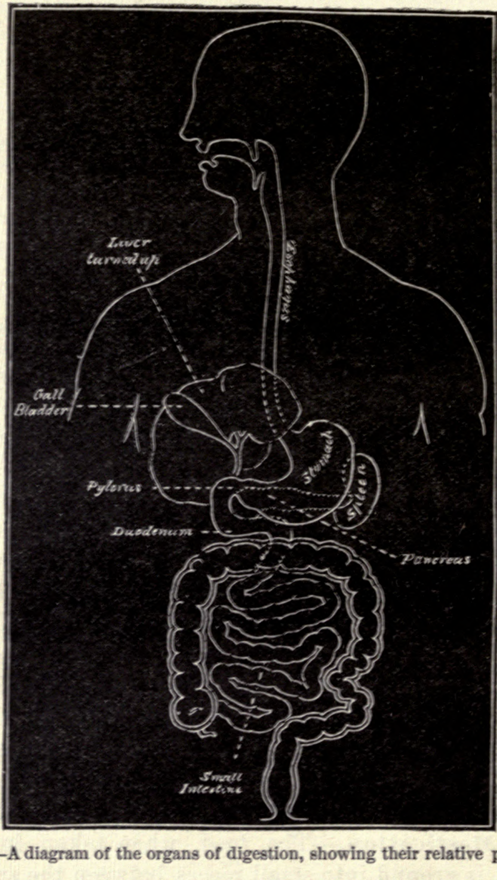

FIG. 40.—A diagram of the organs of digestion, showing their relative positions.

61. The Teeth.—The teeth are the organs which prepare the food for the action of the digestive fluids, and are thirty-two in number. (Fig. 41.) They differ in size and shape; those in front being chisel-shaped,

with serrated edges for biting, while those situated farther back have broad cusped surfaces for grinding the food. On each jaw the four front teeth are called incisors; the next ones, on each side, are known as the canines, from their fancied resemblance to the long, sharp teeth of the dog; then follow two bicuspids, on

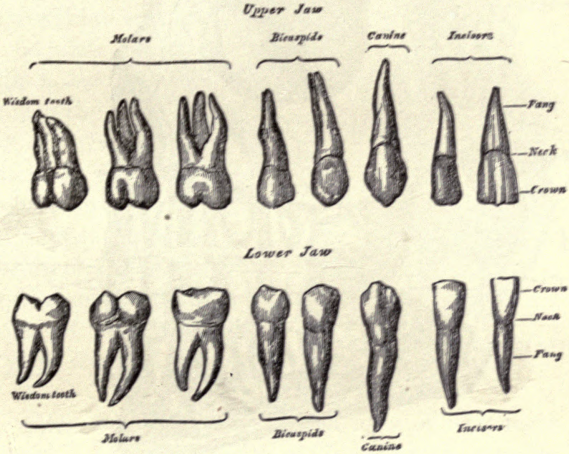

FIG. 41.—Permanent teeth, external view.

each side, with broad surfaces; and lastly are three molars, sometimes called grinders, on each side, with still broader cusped surfaces. The tooth farthest back, on each side, is called a wisdom-tooth, and does not appear until the age of twenty or thereabouts.

The food is largely masticated between the molars; therefore they are large and strong, and placed well back in the mouth, where the muscles of mastication act with the greatest power.

62. Milk-Teeth.—During childhood we are supplied with a set of temporary teeth, twenty in number, known as the milk-teeth. There are eight incisors, four

canines, and eight molars. Between the ages of four and sixteen, often as early as the tenth or twelfth year, these teeth disappear. The roots are absorbed, and the crowns easily removed or pushed aside by the permanent teeth. (Fig. 42.) Care should be taken during these

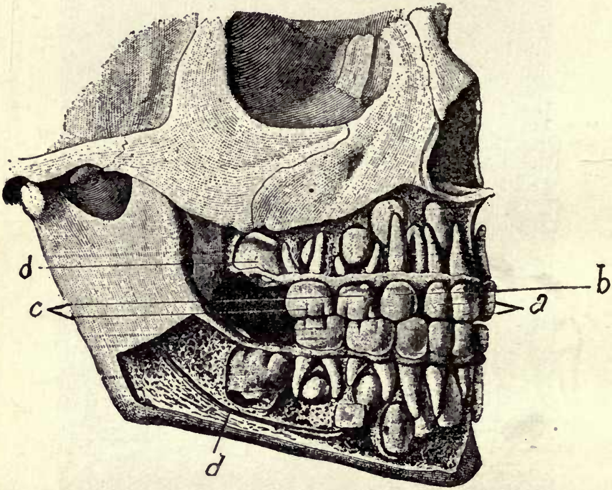

FIG. 42.—Showing first and second sets of teeth: *a*, incisors; *b*, canine; *c*, molars. These belong to the temporary set. The permanent teeth are seen in the jaws at the roots of the first set; *d*, permanent molars.

years that the milk-teeth do not displace the permanent teeth and cause irregularity in their growth. If the first teeth remain too long, and force the new ones to appear on the inside or outside of the jaw, they should be removed, so that the permanent ones may not be crowded.

63. Structure.—The teeth are composed of dentin, cement, and enamel. The bodies and roots are composed of dentin, which is hard and compact like the outer layer of the bones. The roots are covered with a

layer of cement, which holds the teeth firmly in the sockets. The crowns, or the parts projecting from the gums, are covered with a layer of enamel, which is a hard, ivory-like substance much more compact than the dentin which composes the body of the teeth. If a longitudinal section of a tooth be made, it is seen to contain a cavity which extends into the root. This is known as the pulp-cavity, and in this pulp are found the nerves and blood-vessels which supply sensation and nourishment. They enter through a small aperture at the apex of each root, and ramify in the pulp. (Fig. 43.)

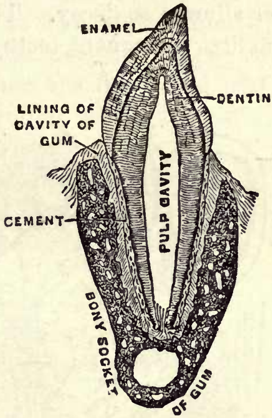

Fig. 43.—A vertical section of a tooth in its socket.

64. Care of the Teeth.—The care of the teeth is important. Little particles of food which remain in the mouth should be removed, lest fermentive changes take place, and the chemical products cause decay of the teeth, and disease of the gums. The secretions of the mouth also undergo changes, and frequent cleansing of the teeth is therefore necessary to prevent the formation of yellow concretions known as tartar. This is harmful to the teeth and gums, as well as unsightly and uncleanly. Substances which corrode the enamel, like the mineral acids, should not be allowed to come in contact with the teeth, for when once the enamel is destroyed, it is never replaced, and decay is sure to follow. Too sudden changes from heat to cold, or the reverse, may crack this outside layer; also the biting of

hard substances, or the use of metal picks. A soft brush is best with which to clean the teeth, and powder with too much grit, or cutting power, should not be used. The temporary teeth should not be neglected, nor allowed to decay. The sixth-year molars, which are the first permanent teeth, should have special attention.

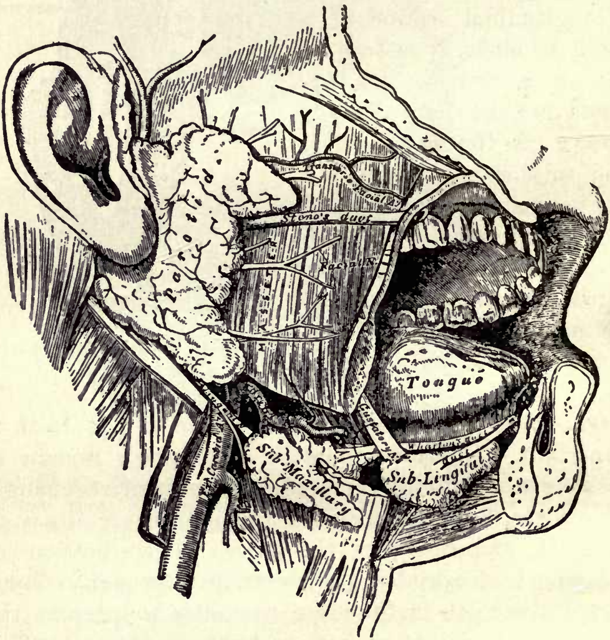

Fig. 44.—Salivary glands with their ducts.

A permanent tooth should never be extracted, except as a last resort. A skilful dentist will save almost any tooth.

65. Secretions of the Mouth.—There are, besides the mucous glands of the mouth, three sets of glands which secrete a slightly alkaline, viscid fluid called saliva.

They are known as the sub-lingual, sub-maxillary, and parotid glands. (Fig. 44.) The sub-lingual are situated in the floor of the mouth beneath the anterior portion of the tongue. A number of small ducts lead from these glands and empty into the floor of the mouth beneath the tongue. The sub-maxillary are farther back, beneath the tongue and against the horizontal part of the lower jaw. A duct, through which the saliva is discharged, leads forward and ends in the floor of the mouth beneath the anterior portion of the tongue. The parotid glands, which are the largest, lie below and in front of the ears, behind and to the outer side of the ascending portions of the lower jaw. Each has a duct, which passes forward and empties on the inner side of the cheek opposite the second molar tooth of the upper jaw. These large glands become swollen and painful in the disease known as the mumps.

The salivary glands are easily excited, and the presence of food, or any hard substance, in the mouth is sufficient to cause a free flow of saliva. The smell of food, and even the thought of a savory dish, may cause "the mouth to water."

66. Properties of the Saliva.—The saliva is a watery, transparent, slightly viscid fluid having an alkaline reaction. It contains an active ferment (ptyalin), which converts boiled starch into sugar. Care should be taken to chew the food well, in order that the saliva may be thoroughly mixed with the food in the mouth and come in contact with each particle of starch, so that the ferment may act as fully as possible. This changing of the starchy elements of the food to sugar is not fully accomplished by the ptyalin, but it is of importance as the first change in digestion. By far the most important action of the saliva is to moisten the food so that it can be easily masticated and swallowed. Ptyalin

has little or no action on starch that has not been boiled or baked, and on the starchy elements that have been well cooked its action is not nearly so thorough as the ferment found farther on in the digestive tract.

67. The Pharynx.—The pharynx is that part of the alimentary canal which connects the mouth and the

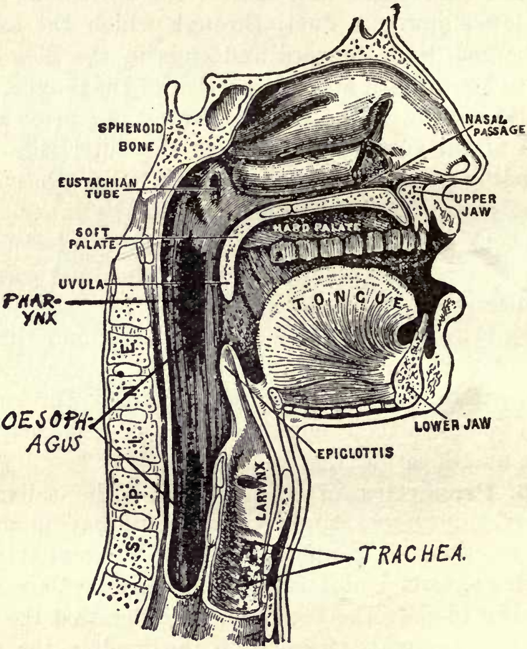

Fig. 45.—Vertical section of nose, mouth, and throat.

œsophagus. (Fig. 45.) The posterior nares or nostrils, the Eustachian tubes, which pass from the ears, and the trachea or windpipe, all open into this cavity. During the act of swallowing, the openings into the nostrils are covered by the uvula, or soft palate ; the opening into the trachea, by the epiglottis. The pharynx is surrounded

by the muscles of deglutition, which contract and force along the food which is being swallowed. The act of swallowing is voluntary until the object passes through the pharynx into the œsophagus; then it becomes involuntary, and the process is completed by the action of the unstriped or involuntary muscular fibers in the walls of the œsophagus.

68. The Œsophagus.—The œsophagus extends from the lower part of the pharynx to the stomach. It passes down the neck a little to the left of the median line, through the thoracic cavity, at first in front, then to the left, of the spinal column, and finally enters the abdominal cavity through an opening in the diaphragm. (Fig. 45.)

69. The Stomach.—The stomach is the largest dilatation in the alimentary canal. It is shaped like a pear bent upon itself, and, when moderately distended, holds about 1.4 liters (3 pints). The opening from the œsophagus is called the cardiac orifice; it opens into the stomach about 7.5 centimeters (3 inches) from its large end, or fundus. The opening which leads into the intestines is situated at the small extremity, and is called the pyloric opening. (Fig. 46.) The fundus lies in the left side of the abdominal cavity below the ribs. The pyloric end reaches to the right of the median line below the anterior border of the ribs. The whole organ moves up and down with the diaphragm during the movements of respiration.

70. Coats of the Stomach.—The stomach is composed of four coats, or layers: the serous, the muscular, the cellular, and the mucous layers. The serous coat is a thin, smooth, transparent membrane which composes the whole outer surface of the stomach. It secretes a thin, glairy fluid, which keeps the surface moist, and allows the stomach to glide smoothly upon the other

abdominal organs during the movements of digestion. The muscular coat consists of three sets of fibers which run transversely, longitudinally, and obliquely. These fibers are of the involuntary type and act during digestion. Near the pyloric end of the stomach, the transverse, or circular, fibers increase in number and form a constrictor muscle, which prevents the contents of the

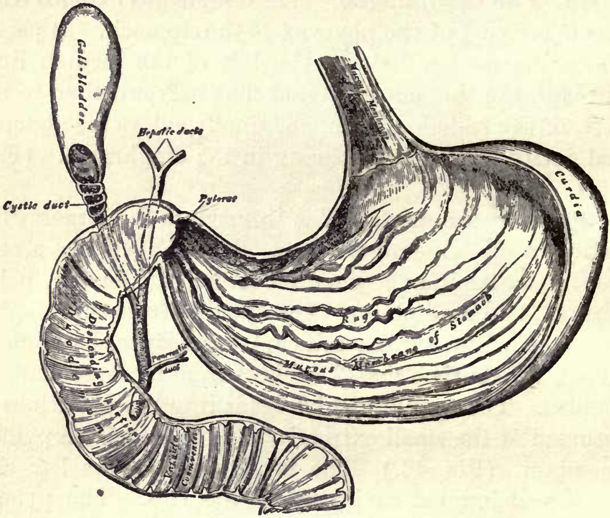

FIG. 46.—The inside of the stomach, showing the folds in the mucous membrane.

stomach from passing into the intestines before the gastric juice has completed its work. The cellular coat consists of a layer of loose connective tissue, which separates the muscular and the mucous coats. It contains the blood-vessels which supply the mucous membrane of the stomach. The mucous coat or lining of the stomach, is a continuation of the mucous membrane of the mouth, pharynx, and œsophagus, and presents much the same appearance to the naked eye. If it be

examined closely with a magnifying-glass, it is seen to be honeycombed with small, shallow depressions, and in these depressions may be seen the orifices of minute tubules. (Fig. 47.) These are the mouths of the gastric follicles, which secrete the ferment of stomach-digestion. These little tubes, or follicles, are surrounded by a network of blood-vessels, the blood of which supplies the material for the product of these glands.

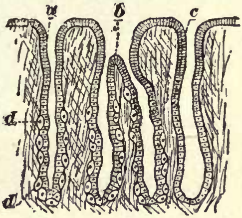

FIG. 47.—A section of the gastric mucous membrane, magnified twenty-five diameters: *a*, a simple peptic gland; *b*, a compound peptic gland; *c*, a mucous gland.

71. The Gastric Juice.—The gastric juice is a thin, watery fluid, acid in reaction, and of a light amber color. It contains a ferment (pepsin), which attacks the albumin and gluten of the food, and produces liquefaction and disintegration of these substances, thus forming peptones. The gastric juice also contains free hydrochloric acid. In order that the pepsin may act, it is necessary that a temperature of about 99° F. be maintained, and that the solution be acid in reaction. The gastric juice is secreted only when some substance is present which irritates or stimulates the mucous membrane of the stomach. Then it is poured forth freely, probably to the extent of 3 or 4 liters (6 or 8 pints) daily.

72. Peristaltic Action.—The movements of the stomach during digestion have been studied by means of artificial openings into the stomach, known as gastric fistulæ, in animals and human beings. If a rod of any kind be introduced through the fistula during digestion, it is grasped by the walls of the stomach, and a gentle twisting or grinding movement is given to the protrud-

ing end. This involuntary movement of the stomach is called its peristaltic action, and is somewhat regular and uniform. When food enters the stomach at the cardiac orifice, it is first passed to the left into the fundus, thence along the lower border, or greater curvature, to the pylorus, then along the upper margin, or lesser curvature, to the fundus again. This rotary movement is kept up so long as food remains in the stomach. By means of these movements the gastric juice is brought into contact with each particle of food.

73. Stomach-Digestion.—In the stomach the gluten of farinaceous substances and the fibrous tissue of vegetables are disintegrated, and the starch is set free as fine granules. The casein of milk and cheese is dissolved, and the oily constituents appear as fatty matter. The connective tissue of adipose substances is broken up, and free fat is found mixed with the contents of the stomach. The fibrous tissue and the sarcolemma of the muscular fibers are eaten away, the substance breaks up into a gruelly mixture, and the fibrils are seen, under the microscope, to have lost their bead-like appearance. After this process has gone on from half an hour to an hour, the digested portion of the food begins to find its way past the constricting muscle at the small end of the stomach, and, in from three to five hours, the stomach is emptied of its contents. The pulpy mass which passes from the stomach is called chyme. It is grayish in color, and is of the consistency of gruel. It contains the starch set free in the stomach, oil, or fat in a fluid condition, and shreds of partially digested muscular and cellular fibers. This grayish mixture passes into the small intestine, where it comes in contact with other ferments, which complete the process of digestion.

74. The Small Intestine.—The small intestine is about 7.2 meters (24 feet) in length, and has the

same construction as the stomach, except that its mucous membrane is thrown into folds (Fig. 48), and is covered with little papules, or villi, through which absorption takes place. (Fig. 49.) In the small intestine digestion is completed and absorption carried on. Very soon after entering the small intestine the partially digested food, or chyme, comes in contact with the pancreatic juice and the bile, both of which play an important part in the processes of digestion and absorption.

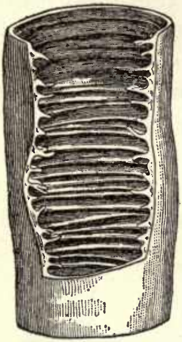

FIG. 48.—The inner surface of the small intestine, showing the folds of the mucous membrane.

FIG. 49.—The papules, or villi, of the mucous membrane of the intestines, highly magnified.

75. The Pancreas.—The pancreas is situated back of the stomach, its small end, or tail, reaching to the left as far as the fundus. It is shaped somewhat like a dog's ear (Fig. 50), and secretes a fluid which closely resembles the saliva. The gland has an excretory duct, which enters the intestine about a decimeter (4 inches) from the pyloric end of the stomach.

76. Pancreatic Digestion.—As soon as the food which has passed through the stomach comes in contact with the pancreatic juice, a remarkable change takes place. The fats, which have been unaffected thus far by the saliva and gastric juice, are quickly broken up into minute globules, and held in suspension, forming what is known as an emulsion. This is called

the chyle, and in this form it is absorbed into the system.

The starchy matter of the food is also transformed with equal rapidity. Starch, which has been set free by the action of the gastric juice, comes in contact with the ferment known as pancreatin, and is quickly changed to sugar, which is soluble and readily absorbed. Its action is much more rapid than that of the ptyalin of the saliva, and it affects raw starch almost as readily as that which has been cooked.

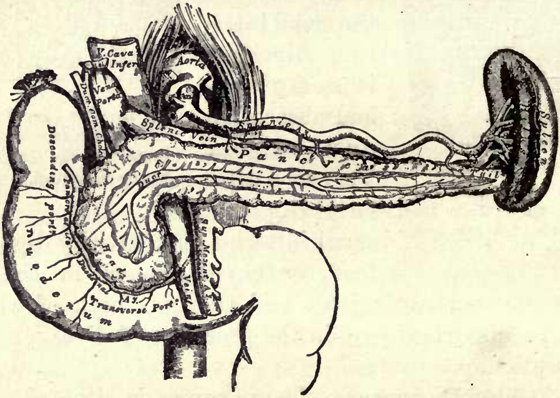

FIG. 50.—The pancreas, showing its position and relation to other organs.

Animals from which the pancreas has been removed die in a short time, because of the arrest of digestion and the absorption of starchy materials.

The pancreatic juice also has some effect upon the albuminoid substances which may have escaped the action of the gastric juice. This change is not so marked as that which takes place in the stomach, but is of considerable importance. The action of the pancreatic juice is thus seen to be threefold; it forms with the fats a fine emulsion, turns starch into sugar, and

converts the albumin—which may have escaped the action of the gastric juice—into peptones.

When the partially digested food comes in contact with the pancreatic juice, it also meets the secretion from the liver.

77. The Liver.—The liver is the largest gland in the body (Figs. 51 and 51*a*), its weight in the adult being nearly 2 kilograms (4 pounds). It is situated in the right side of the abdominal cavity, its rounded upper surface lying close to the diaphragm, its border corresponding nearly to the margin of the ribs or chest-wall. In a cleft, or notch, in the under surface, is a sac or pouch called the gall-bladder, in which the bile is stored. (Fig. 51*a*.)

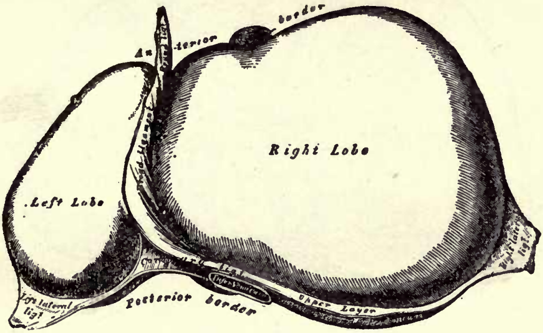

FIG. 51.—The upper surface of the liver, showing the two lobes.

78. The Bile.—The bile is secreted by the liver in large quantities, more than a liter (between 2 and 3 pints) daily, and is discharged directly into the small intestine with the pancreatic juice, or stored in the gall-bladder when digestion is not going on. It is more or less ropy in character, neutral or alkaline in reaction, and has a slight animal odor. If the bile be withdrawn from the alimentary canal, the animal soon

shows signs of emaciation, and finally dies from starvation, although the appetite may be good. The bile is in part an excretion, but it is largely reabsorbed, and passes into the circulation with the products of digestion. Its absolute function is not fully understood, but it is supposed to be a deodorant and a disinfectant. It also quickens peristalsis and promotes the absorption of starchy and fatty foods. It may be instrumental in

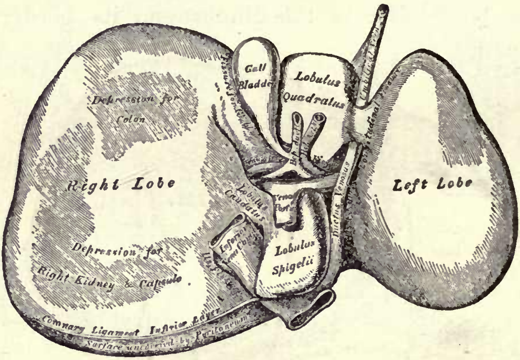

FIG. 51*a*.—The nnder surface of the liver, showing the lobes and the gall-bladder.

breaking up the oil-globules into fatty acids and glycerin, but this is a slow process, and not of great importance, as the greater part of the fat is absorbed in the form of an emulsion.

The whole process of digestion is completed in the small intestine, and the digested material absorbed for the sustenance of the body. Partially digested muscular fiber, strands of connective tissue, and undigested vegetable substances, together with traces of the digestive ferments and the coloring matter of the bile, are passed into the large intestine and discharged from the body as effete matter.

79. Effect of Alcohol on Digestion.—Alcohol taken into the stomach acts as an irritant.

If alcohol be dropped into the eye, it makes the eye look red and causes the tears to flow freely.

Its effect upon the lining of the stomach is very similar.

If a small quantity be taken, it causes a sense of warmth, because of its local action on the mucous membrane.

The capillary network of the stomach is stimulated.

The surface becomes red and slightly congested because of the increased blood-supply, and the secreting glands pour forth their fluids more abundantly.

This increased activity of the glands weakens the power of the gastric juice to dissolve food.

A larger dose will arrest the process of digestion by destroying the activity of the gastric juice. The pepsin which it contains is thrown down as a precipitate and becomes an inert substance incapable of acting upon the albuminoids.

The habitual use of alcohol produces important changes in the mucous membrane of the stomach.

The mucus secreted becomes thick and viscid, and the gastric juice is so changed that it performs its duty with difficulty. The result is alcoholic dyspepsia, or chronic inflammation of the inner coats; the mucous membrane becomes permanently congested, the connective tissue of this membrane is greatly developed, the walls of the stomach are thickened, and the gastric follicles, the secreting glands which supply the pepsin of the gastric juice, shrink or are obliterated.

80. Effect of Alcohol on the Liver.—The liver, like all other organs, is made up of cells. Alcohol is largely absorbed by the stomach and passes directly to the liver, causing an over-stimulation of this organ.

Over-stimulation of any glandular apparatus, if long continued, produces structural changes in the gland.

The connective tissue, which forms the glandular framework, increases in quantity. This newly formed tissue of the gland has a tendency to contract and to destroy the secreting cells, and the gland is permanently injured or completely destroyed. This effect is well shown in *cirrhosis* of the liver, due to alcohol.

There is at first a congestion of the gland, formation of new connective tissue, and an increase in size of the whole organ. Finally contraction begins, and the liver becomes small and hard, while the surface presents the peculiar nodular appearance which has given it the name of "hob-nail" or drunkard's liver.

A liver in this condition cannot properly secrete bile, and thus digestion is impaired.

"It is commonly thought that alcoholic drinks act as aids to digestion. In reality it would appear that the contrary is the case."—G. Bunge, Professor of Physiological Chemistry at Basle, Switzerland.

Professor Duggan, of Johns Hopkins University, found that alcohol in any form retarded the digestion of starch.

Professor Paul Bert found that even small doses of alcohol delayed digestion, until it was absorbed from the stomach.

Dr. Beaumont's experiments on Alexis St. Martin all went to prove that alcohol hinders digestion.

"When alcohol (diluted) is swallowed it is quickly absorbed by the capillary blood-vessels of the gastric mucous membrane. An exception to the rapid absorption of alcohol sometimes occurs when a large quantity of raw spirits is taken. Many cases are recorded where men for a wager have drunk a bottle of whisky or brandy. The result is often sudden death; but some-

times no effect is noticed for fifteen or twenty minutes, then there is sudden unconsciousness, passing into stupor, which ends in death; in such cases the large quantity of strong spirits seems temporarily to paralyze the absorbing power of the stomach."—H. Newell Martin, Professor of Biology and Physiology in Johns Hopkins University.

QUESTIONS ON DIGESTION.

1. What is the alimentary canal?
2. What processes take place in it?
3. What is the purpose of mastication?
4. Describe the teeth. Name them.
5. Describe the structure of the teeth.
6. What can you say of the care of the teeth?
7. What glands are located in the mouth?
8. What do these glands secrete, and what are the properties of these secretions?
9. Describe the pharynx.
10. Describe the stomach.
11. Name and describe the coats of the stomach, and tell the use of each.
12. What is the gastric juice, and what is its use?
13. What is known of the movements of the stomach?
14. Describe the process of stomach-digestion.
15. What is the chyme?
16. Describe the small intestine.
17. What is the pancreas?
18. What can you say of pancreatic digestion?
19. Describe the liver.
20. What is known of the bile and its action?
21. When does absorption take place?
22. What effect has alcohol upon the stomach?
23. How does alcohol affect the liver?
24. Is alcohol an aid to digestion?

EXPERIMENTS ON DIGESTION.

1. Obtain specimens of teeth for sawing and splitting. Teeth of animals as well as those of human beings may be used.

2. Diagrams of the digestive apparatus should be drawn by all the pupils.

3. The action of the digestive ferments may be shown by experimenting, upon white of eggs, milk, oil, and starch, with weak solutions of pepsin and pancreatin obtained from the druggist.

4. Tripe, and the stomach of the pig, calf, and lamb may be obtained from the butcher, and examined both with and without the microscope.

5. A small liver, of a sheep or calf, with the gall-bladder attached, should be obtained and examined.

CHAPTER VIII.

ABSORPTION.

81. Absorption.—After the food taken into the system has been digested, it has yet to be taken up and carried to all parts of the body. The process by which these food-materials find their way through the walls of the intestines into the general circulation is called *absorption,* and it is accomplished by a special arrangement of the mucous membrane which lines the intestinal cavity.

The whole surface of this membrane is covered with a great number of fine, hair-like processes, which give to it a smooth, velvety appearance. These projections are called *villi.* They are about 8 millimeters ($\frac{1}{30}$ inch) in length, and so close together that about twenty-five hundred are found on a square centimeter of surface. (Figs. 52 and 52*a*.)

82. Lacteals.—Each one of these little projections contains a network of very small blood-vessels which surrounds a hollow space, this space being the peripheral end of a system of vessels known as the *lacteals* or *lymphatics*. Each minute branch of this system, as it leaves a villus, unites with other branches, which, in turn, join each other, and finally form, opposite the second lumbar vertebra, an enlargement known as the *receptaculum chyli.* From this point a duct, the thoracic duct, about the size of a goose-quill, leads upward through the chest-cavity, and empties into a large vein just before it enters the heart. These lymphatics, or

lacteals, as they are more frequently called, are only a part of the lymphatic system, which extends throughout the whole body. (Fig. 53.) Its various branches extend over the system and converge to this same point, viz., the large vein near the heart.

Absorption takes place through the walls of the villi,

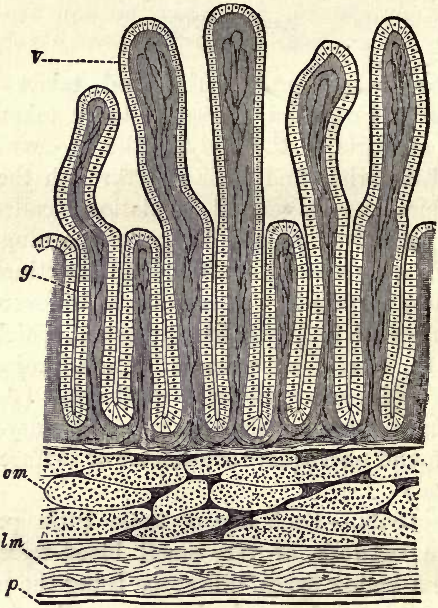

Fig. 52.—Diagram to show the structure of the wall of the small intestine: *v*, villi; *g*, glands of the mucous membrane; *cm*, circular-muscle layer; *lm*, longitudinal-muscle layer; *p*, serous coat.

a part of the absorbed material finding its way into the lacteals, and a part passing directly into the blood-vessels that ramify in the villi.

While each minute branch of the lymphatic system is engaged in carrying away the digested foods, the small

blood-vessels which form a complete network in each villus are also taking up the sugars in large quantities.

These little blood-vessels seem to have an affinity for the sugar and peptones, and the greater part of these products find their way into the circulation through them.

A little of the emulsified fat also finds its way directly

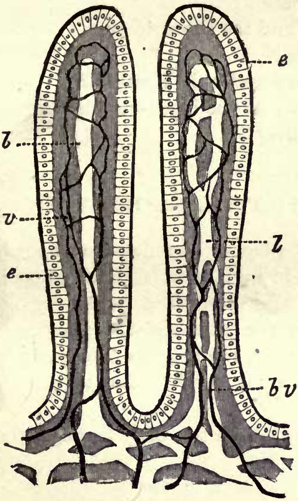

FIG. 52*a*.—Two villi, highly magnified: *e*, *e*, epithelium; *bv*, blood-vessels; *l*, lacteals.

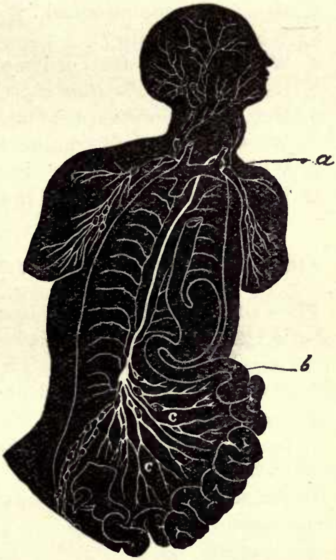

FIG. 53.—Lacteals and lymphatics during digestion: *a*, thoracic duct; *b*, an intestine; *c*, lymphatics.

into the blood-vessels, but this is small in comparison with the amount taken up by the lacteals.

The blood, as it flows from the intestine with its load of digested food, passes directly to the liver, where the sugars are quickly taken up and stored away, to be given off as the system requires. The liver is a gland with a

double function: it secretes the bile which aids in the digestive process, and it acts as a storehouse for the sugars, and thus prevents an overcharging of the blood with these substances.

QUESTIONS ON ABSORPTION.

1. After the food has been digested what becomes of it?
2. How is this accomplished?
3. What are the villi?
4. What are the lacteals or lymphatics?
5. Define the *receptaculum chyli*, and the thoracic duct.
6. How does absorption take place?
7. What parts of the food are taken up by the lacteals?
8. What foods are taken up directly by the blood-vessels?
9. What are the functions of the liver?

EXPERIMENT TO ILLUSTRATE ABSORPTION.

Place a thick liquid—as molasses, glue, or mucilage, or a saturated solution of copper sulphate—in a glass, as a glass tumbler, or a straight lamp-chimney. Tie a piece of firm paper, or an animal membrane of any kind, over the mouth of the glass, and immerse it in a vessel of water, adjusting the height of the glass so that the liquids shall stand at the same level. The liquid will soon be seen rising in the glass.

In the same way absorption takes place in the body through the membranes.

CHAPTER IX.

THE BLOOD.

83. The Blood.—The blood is the circulating fluid, or medium, which carries to all parts of the system the supply of building material needed for repairing the waste of the body, and at the same time carries the waste materials to the various excretory organs of the body. It may be called the common carrier of the system, and since waste and repair are constantly going on, its round is never ceasing. The heart, beating seventy or eighty times a minute, sends at every beat its charge of blood into the vessels which carry it throughout the body, and, as the heart relaxes, it is quickly filled by the returning blood. Again it contracts, and forces the blood onward, and in this way a constant flow is maintained.

84. Composition of the Blood.—The blood is a thick, somewhat viscid fluid, varying in color from a brilliant scarlet to a very dark purple, according to the part of the circulatory apparatus from which it is obtained; that in the veins being dark, generally speaking; and that in the arteries, a bright red.

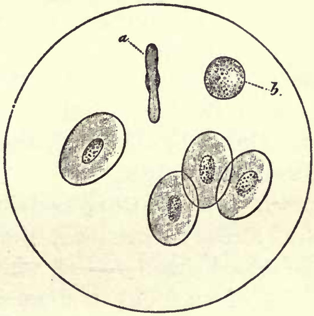

FIG. 54.—Blood-globules of a frog: *a*, a red globule seen sideways; *b*, a white globule.

It is composed of two substances—*corpuscles* and *plasma*.

85. The Corpuscles.—The corpuscles appear, under the microscope, as small disks with a shallow depression in the center, and smooth, rounded edges. (Fig. 54.)

These little bodies are exceedingly small, being about 7 microns ($\frac{1}{3500}$ of an inch) in diameter, while their thickness is very much less than this.

When placed on the slide of a microscope, they have a tendency to arrange themselves in rows, or rings, with their flattened surfaces together.

They are of a pale amber tint when viewed alone, but when seen in large numbers they are of a bright red, and give to the blood its brilliant color.

These corpuscles, or blood-globules, as they are often called, are composed largely of a red coloring matter, *hemoglobin,* which comprises about eighty per cent. of the solid constituents. The remaining twenty per cent. is made up of albuminous matter, salt, and water.

The corpuscles in the blood of the lower animals are smaller than in man as a rule. Those of the monkey correspond very closely to those in human blood, while those of the elephant are very much larger. It sometimes becomes necessary to determine the nature of blood-stains upon garments, and, because of this difference in the size of the corpuscles, human blood may sometimes be detected, though the microscope is not always a sure test.

86. White Corpuscles.—Besides the red corpuscles, already described, there may be seen floating in the blood small round white bodies, about 10 microns ($\frac{1}{2500}$ of an inch) in diameter, called white corpuscles. They are much less numerous than the red, being in the proportion of one to about three hundred. They are transparent, with a somewhat granular center, and within their substance may be seen from one to three nuclei.

87. Amœboid Movement.—This peculiarity of the white corpuscles may be observed when blood is drawn from a blood-vessel and kept at the right temperature; there may be seen, pushing itself out from the side of the corpuscle, a thin, transparent prolongation. This slender projection enlarges, draws to itself the nuclei and granular center of the corpuscle, and becomes the principal part of the object; while the part which at

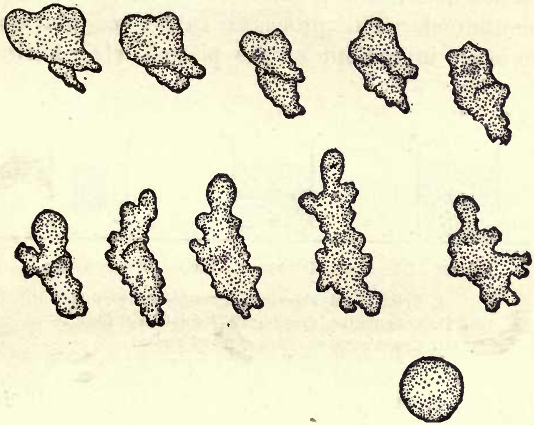

FIG. 55.—Changes in the white corpuscles of a frog.

first was the cell proper appears as a prolongation, which is finally drawn into the corpuscle, and it can be seen that the whole object has moved from one place to another. (Fig. 55.) This movement can be seen best in the amœba, from which it takes its name, a low form of animal life found in fresh-water ponds and ditches.

88. The Plasma.—The plasma is a clear, colorless liquid, heavier than water, having an alkaline reaction. It is composed of water, holding in solution albumin, the salts of lime, soda, and potash, and two other sub-

stances, viz.: *paraglobulin,* which is closely allied to the albumin found in the plasma, and *fibrinogen,* which is concerned in the coagulation of the blood.

The corpuscles, both red and white, are suspended in the plasma, which carries them on their rounds through the channels of circulation.

89. Coagulation.—When blood is taken from the body and allowed to stand for a short time, it becomes a gelatinous mass, taking the form of the vessel in which it is contained. This process is called coagulation, and is due to an ingredient of the plasma, viz.: fibrinogen.

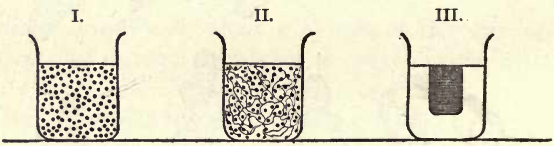

FIG. 56.—Diagram to illustrate the process of coagulation.

I. Fresh blood, showing corpuscles and plasma.
II. Coagulating, showing the formation of fibrin.
III. Coagulated, showing clot and serum.

During the clotting process this substance is turned to fibrin, and entangles the corpuscles in its meshes. The corpuscles take no part in the process, and form a portion of the coagulum only as they are caught and held by the solidifying mass. When once the clot is formed it begins to contract. It at first clings to the vessel in which it stands, but, as contraction goes on, it leaves the sides of the receptacle, while the space around the contracting clot is filled by a watery fluid called *serum,* which is pressed from the jelly-like mass by the force of the contraction. (Fig. 56.) In this way the blood has entirely changed its character. Before coagulation the blood consists of corpuscles and plasma; after coagulation, of clot and serum.

Dalton gives the following table:

Blood before coagulation consists of—

I., globules (corpuscles),

and, II., plasma, containing $\begin{cases} \text{fibrinogen,} \\ \text{albumin,} \\ \text{paraglobulin,} \\ \text{water,} \\ \text{salts.} \end{cases}$

After coagulation it is separated into—

I., clot, containing... $\begin{cases} \text{fibrin,} \\ \text{globules.} \end{cases}$

and, II., serum, containing $\begin{cases} \text{albumin,} \\ \text{paraglobulin,} \\ \text{water,} \\ \text{salts.} \end{cases}$

This process of clotting is one of the wise provisions of nature. It is nature's way of stopping the drain upon the system when the smaller blood-vessels are opened by accident. If the skin of the body be broken or cut, blood at first flows freely, but as soon as coagulation begins to take place the flow is less abundant and finally stops entirely. If now the wound be examined closely, it will be found to contain a clot, which has choked the mouths of the little blood-vessels and arrested the flow of blood. In this way nature becomes her own surgeon, and the damaged part is soon repaired. In a few persons the blood seems to be deficient in the fibrin-producing element. Clotting does not take place, and bleeding is arrested with difficulty. Such persons are knows as "bleeders," and life is endangered by any injury to the skin or mucous membranes.

90. Quantity of Blood.—It has been estimated that the amount of blood is $\frac{1}{13}$ of the body's weight, so that a man weighing 65 kilograms (143 pounds) has within the vessels of circulation 5 kilograms (11 pounds)

of blood, and this blood is kept in constant motion by the action of the heart, carrying to the various tissues of the body materials which are constantly needed to repair the waste, and taking from the tissues the substances which have served their purposes, and are ready to be thrown off from the body.

CHAPTER X.

THE HEART AND BLOOD-VESSELS.

91. The Heart.—The heart is the propelling force, the *vis a tergo,* that sets in motion the whole volume of blood, and keeps the mass constantly moving through the network of blood-vessels.

It is shaped somewhat like a pear, with its apex downward and outward. (Figs. 57 and 57*a.*) Generally speaking, its apex-beat may be seen and felt about 5 centimeters (2 inches) to the left and a little above the lower end of the sternum. Its base is near the median line of the chest, beneath the sternum, on a level with the third rib. (Fig. 58.)

This hollow muscular organ weighs from 227 to 340 grams (8 to 12 ounces), and is composed of fibers which run transversely, longitudinally, and diagonally. It is enclosed in a sac composed of serous membrane, called the pericardium, which entirely encloses it, and secretes a lubricating fluid closely resembling the serum of the blood or the lymph of the lymphatic vessels.

92. Cavities of the Heart.—The heart is divided into four chambers, or cavities, known as auricles and ventricles.

The auricles are situated at the upper and large end of the heart, and derive their name from their fancied resemblance to a dog's ear. Their walls are thin, and do not possess the degree of contractile power found in the walls of the ventricles. They have the appearance

of appendages, or of dilatable, flaccid sacs which receive the blood returning from its round of circulation, rather than that of part of the heart proper.

The blood, which flows into them, passes into the

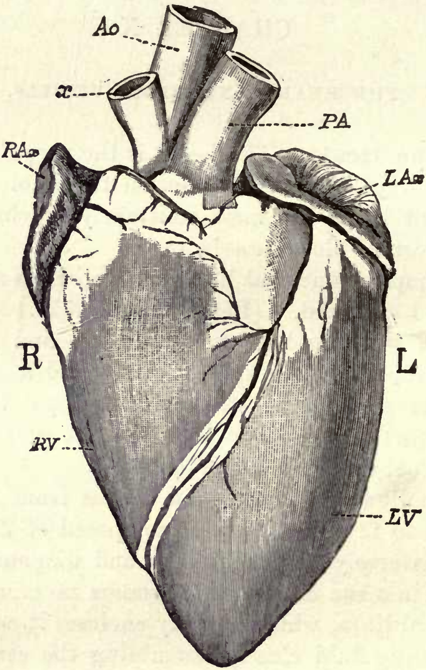

FIG. 57.—A sheep's heart, front view: *R*, right side; *L*, left side; *RV*, right ventricle; *LV*, left ventricle; *RAx*, appendix of right auricle; *LAx*, appendix of left auricle; *PA*, pulmonary artery; *Ao*, aorta; *x*, its first large branch.

ventricles during relaxation of the heart, largely from the force of gravity and the pressure from behind of the returning blood-current, though the auricular walls possess some power of contraction. When distended, the auricles are capable of holding about 60 cubic centimeters ($\frac{1}{3}$ of a gill) each.

93. Openings.—Blood-vessels which contain the blood returning from the various parts of the system open into the auricles. Into the right auricle the two large veins, one returning from the head and upper

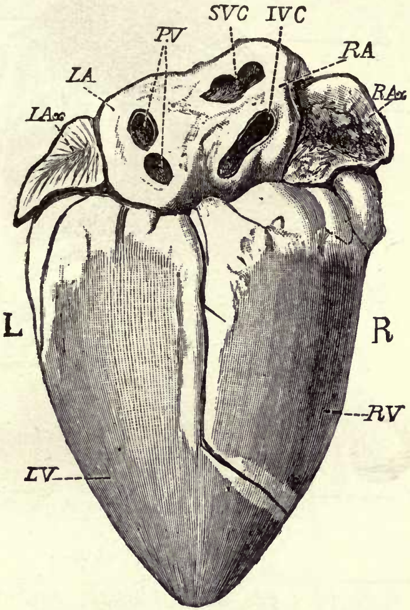

FIG. 57*a*.—A sheep's heart, back view: *R*, right side; *L*, left side; *RV*, right ventricle; *LV*, left ventricle; *LA*, left auricle; *LAx*, appendix of left auricle; *RA*, right auricle; *RAx*, appendix of right auricle; *SVC*, opening of superior vena cava; *IVC*, opening of inferior vena cava; *PV*, openings of pulmonary veins.

extremities, and the other from the trunk and lower extremities, pour their blood; and into the left auricle the pulmonary veins, four in number, discharge the blood from the lungs. (Figs. 59 and 60.)

94. The Ventricles.—The ventricles furnish the power which sets the blood in motion, and their walls

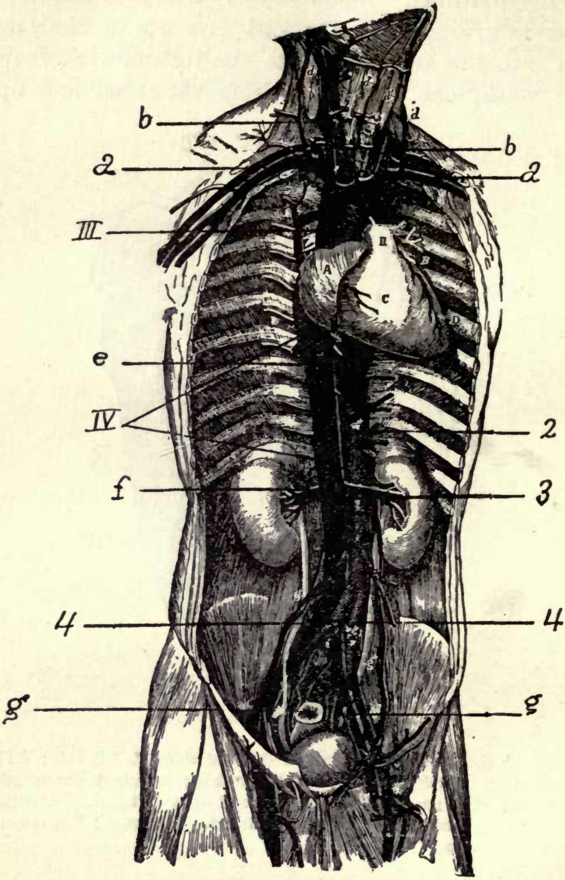

FIG. 58.—Heart and vessels of the trunk, showing position of organs: *A*, right auricle; *B*, left auricle; *C*, right ventricle; *D*, part of left ventricle; *I*, aorta; *II*, pulmonary artery; *III*, superior vena cava; *IV*, inferior vena cava; 1, carotid arteries; 2, arteries for diaphragm; 3, arteries for kidneys; 4, arteries for legs; *a–a*, veins uniting to form the superior vena cava; *b–b*, internal jugular veins; *d–d*, external jugular veins; *e*, veins from liver; *f*, veins from kidney; *g*, veins from legs.

are composed of thick, heavy muscular tissue whose fibers are interwoven and run in various directions. One set passes around the organ, and its fibers are known as annular fibers; another set passes along the greater axis of the heart; while a third set runs diago-

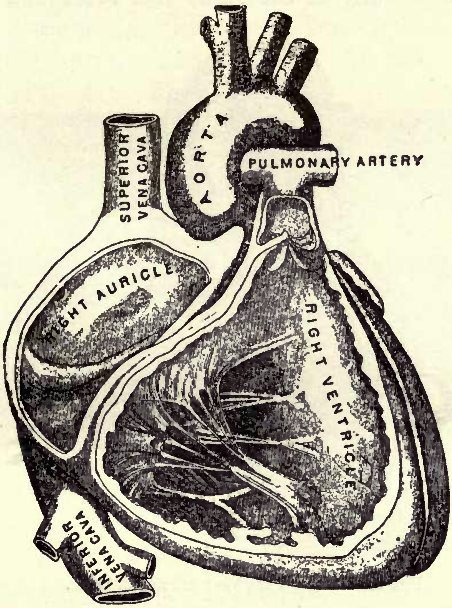

Fig. 59.—Diagram showing right side of heart.

nally or spirally. Some authors give seven layers, but they are so interlaced that they form one compact structure.

The fibers which compose the heart are somewhat peculiar.

Although the heart is an involuntary organ, its muscular fibers are not of the involuntary type. The fibers are smaller, and the striæ are imperfectly shown. They

are square, or block-shaped (Fig. 12, page 12), and are separated only by very thin layers of connective tissue.

If the large fleshy part of the heart be cut through transversely, the cavities of the ventricles are well shown. The right is in the form of a crescent, while the left is round. The walls of the right side are much thinner

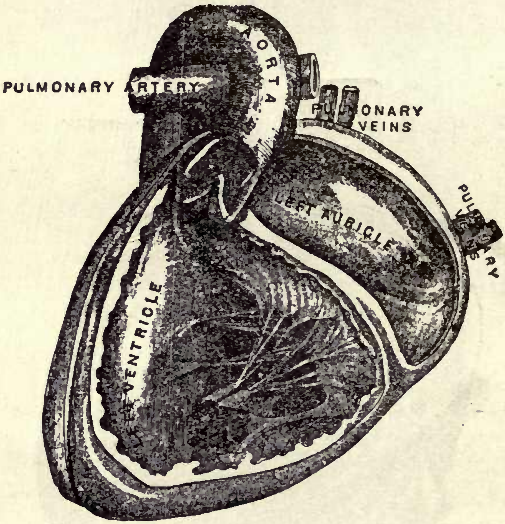

FIG. 60.—Diagram showing left side of heart.

than those of the left, and the left cavity is more rigidly open than the right.

The thickness of the walls of the various chambers of the heart corresponds to the amount of work to be done by each. The auricular walls are thin, the left being a trifle heavier ; while the ventricular walls are thick, the left being much stronger, as the greater part of the work falls upon this part of the heart.

95. Valves of the Heart.—Each auricle communi-

cates with the ventricle of the corresponding side, and in the orifice between the two cavities is found a valve which prevents the blood from flowing back into the auricle when the ventricle contracts upon its contents.

The valve guarding the orifice in the right side of the heart is called the *tricuspid* (Figs. 61 and 62), and is composed of three flaps of strong fibrous tissue with closely fitting edges. The valve in the left side is

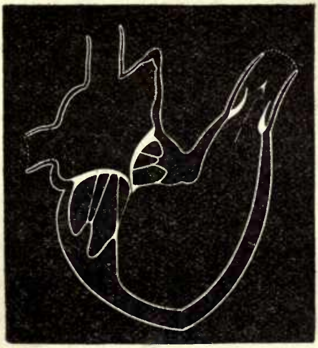

Fig. 61.—Showing action of valve in right side of heart. Tricuspid valve closed.

Fig. 62.—Showing action of valve in right side of heart. Tricuspid valve open.

called the *bicuspid* or *mitral*, and is composed of two flaps similar to those of the tricuspid. These valves are composed of folds of the lining membrane of the heart, known as the endocardium. From the under or ventricular surface of these valves (Fig. 63) extend little fibrous strands (*chordæ tendineæ*), which are attached to little papillary muscles on the inner side of the ventricles. These little tendons are put on the stretch with each contraction of the heart, and hold the valves firmly in position while the strain is upon them.

Besides these openings into the ventricles (auriculo-ventricular) there is found leading from each a vessel

which carries the blood from the heart; viz.: from the right ventricle, the pulmonary artery, and from the left ventricle, the aorta, the largest blood-vessel in the body. The openings of these vessels are guarded by semilunar valves. (Fig. 63.) Each valve is composed of three flaps of fibrous tissue, and prevents the return

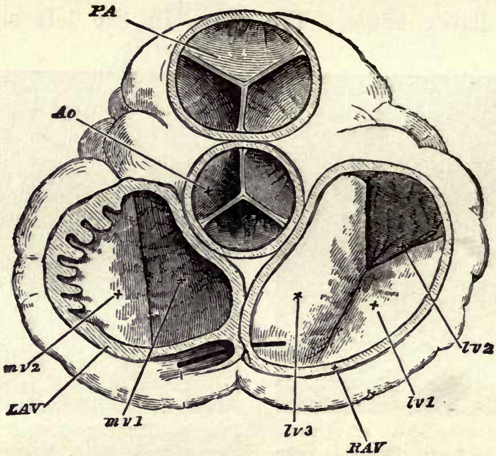

Fig. 63.—Showing the orifices and valves of the heart, the auricles and vessels being cut away: *Ao*, aorta; *PA*, pulmonary artery with its closed semi-lunar valves; *RAV*, opening between right auricle and ventricle, closed by the three flaps (*lv* 1, *lv* 2, *lv* 3) of the tricuspid valve; *LAV*, opening between the left auricle and left ventricle, closed by the two flaps (*mv* 1, *mv* 2) of the bicuspid or mitral valve.

of blood when once it is forced into the blood-vessels. The heart is essentially a double organ. There is no direct communication between the two auricles, or the two ventricles. Each part of the heart acts independently, and sends its charge of blood on a separate and independent round. The right side sends the blood to the lungs for purification and aëration; the left forces the blood to all parts of the system for purposes of repair.

96. The Blood-Vessels.—The blood-vessels are the channels or tubes through which the blood is forced by

FIG. 64.—Diagram (schematic) of the circulation: *a*, heart; *b*, lungs; *c*, head and upper extremities; *d*, spleen; *e*, intestines; *f*, kidneys; *g*, lower extremities; *h*, liver.

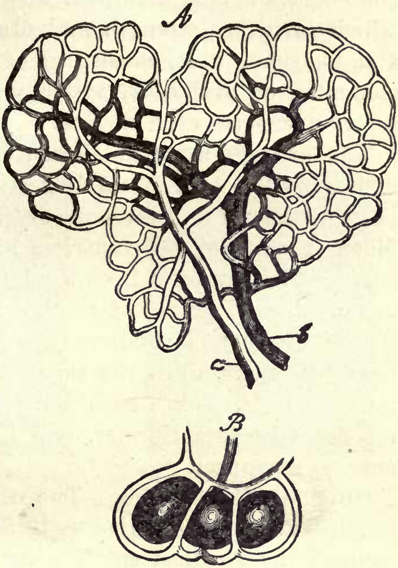

FIG. 65.—*A*, showing capillary network: *a*, arterial branch; *b*, venous branch. *B*, the capillaries of three cells.

the contraction of the heart. These vessels are divided into three sets or classes: the arteries, which carry the blood from the heart; the capillaries, which unite the arteries and veins; and the veins, which return the blood to the heart.

97. The Arteries.—The arteries are composed of three coats: an outer layer of rather loose connective tissue,

which surrounds these vessels and separates them from the tissues through which they pass; a middle coat, composed of muscular fiber and yellow elastic tissue, which furnishes strength and elasticity to the vessels; and an inner coat, consisting of a layer or layers of elongated or oval cells, which gives the inside of the artery a smooth, even surface.

The arteries are the efferent vessels of the heart conveying the blood from this organ. They form two large trunks: the *pulmonary artery*, which carries the blood from the right ventricle to the lungs; and the *aorta*, which carries it from the left ventricle to the various organs and tissues of the body. (Fig. 64.) These trunks divide and subdivide as the distance from the heart increases, until the smallest branches are nearly imperceptible. With each division the outer and middle coats become thinner, and in the capillaries they entirely disappear.

98. The Capillaries.—The capillaries, as the name implies, are minute, hair-like tubes, or channels, which connect the smallest subdivisions of the arteries with the veins. They are about 2 millimeters ($\frac{1}{12}$ of an inch) in length, though some are much shorter.

Their walls are composed of a single layer of the cells which form the inner coat of the arteries. These minute tubes, varying from 8 to 10 microns ($\frac{1}{3000}$ to $\frac{1}{2500}$ of an inch) in diameter (Fig. 65), form meshes or nets, dividing and uniting in various shapes and directions; and during the passage of the blood through this network, its nutritious principles pass through the cell-walls of the capillaries to the tissues, and the tissues give to the moving current of blood a part of their used-up materials.

99. The Veins.—The veins are the afferent vessels of the heart. They receive the blood from the capil-

laries and conduct it to this central organ. They have three coats similar to those of the arteries. The outer and middle coats are much thinner, and the inner coat is continuous with that of the arteries and capillaries.

100. Valves.—Along the course of the veins are valves which are similar to those found at the begin-

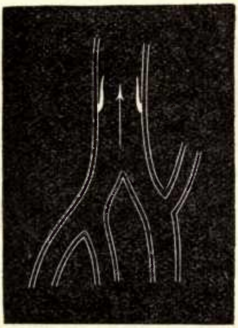

Fig. 66.—Diagram illustrating the action of the valves in the veins. (Valve open.)

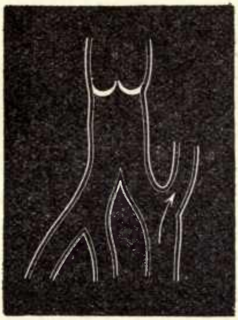

Fig. 66*a*.—Diagram illustrating the action of the valves in the veins. (Valve closed.)

ning of the aorta and the pulmonary artery. (Figs. 66 and 66*a*.) They are often found at the point of union of two veins, and their action can be seen by forcing the blood backward on the peripheral side of the junction of the two veins. They prevent a backward flow of the blood, which might be caused by external pressure, or by muscular contraction.

CHAPTER XI.

CIRCULATION OF THE BLOOD.

101. Circulation.—By circulation of the blood is meant the movement of the contents of the blood-vessels which each impulse of the heart induces. Each contraction of the heart sends its charge of blood into the arteries leading from this organ, and this is, in turn, forced along by the blood sent forward during the next heart-beat.

When a given charge of blood from the ventricles has passed through the various divisions and subdivisions of the arteries, has traversed the network of capillaries which permeate the tissues, has been through the veins, has collected in the auricles, and has returned to the ventricles, it has completed one round of circulation.

102. Passage of the Blood through the Heart.—The heart is as distinctly a double organ as though the right auricle and ventricle were in the right side of the chest and the left auricle and ventricle in the left side of the chest, with the lungs between them. The ventricles act in concert; but before the blood from the right side enters the left side of the heart it is forced through the capillary network of the lungs. The blood which flows to the heart through the large veins passes into the right auricle, and, during the expansion of the ventricle, is discharged into this cavity through the auriculo-ventricular opening. The ventricle then contracts, the valve which guards the opening between the auricle and ventricle is closed, and the blood is forced into the

pulmonary artery and carried to the lungs. It is then forced through the capillaries of the lungs, and returned to the left auricle by the pulmonary veins. It is thus seen that the work of the right heart is to force the blood through the lungs for purification. When the blood returns to the heart it flows into the left auricle, passes through the bicuspid, or mitral, valve to the left ventricle during its expansion; and, upon contraction of this portion of the heart, it is forced into the aorta. The course of the blood is from the right to the left side; from right auricle to right ventricle, to lungs, to left auricle, to left ventricle, and from left ventricle through the general circulation to the tissues of the body. (Fig. 67.)

103. Sounds of the Heart.—With each contraction and relaxation of the heart, there are sounds which may be heard distinctly if the ear be held to the chest-wall over the cardiac region. These sounds are known as the first and second, or the *systolic* and *diastolic* sounds. They are roughly represented by the two words "lub dup" spoken quickly, with a short period of rest before each repetition. The first sounds is the louder, and its tone is somewhat more prolonged, though not more distinct, than the second, which is short and sharp.

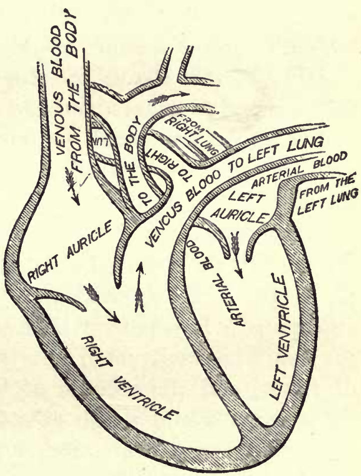

Fig. 67.—Showing the course of the blood through the heart.

They are purely mechanical, being made by the closing of the valves which guard the several openings of the ventricles. The first sound occurs with the contraction of the ventricles, and is caused by the sudden closure of the auriculo-ventricular valves. The second sound occurs with the relaxation of the ventricles, and is due to the closure of the semi-lunar valves at the openings of the aorta and pulmonary artery.

104. Period of Rest.—After each contraction of the ventricles there is a short period of rest, during which the heart lies in a relaxed condition. During this period, blood is being poured into the ventricular cavities, and the heart-muscle itself is repairing the damage done to its structure during its previous contraction. Were it not for this short interval, the heart would soon wear out and become a useless, flabby organ, incapable of vigorous contraction, and without power to respond when the system requires a more rapid circulation of blood.

105. Work Done by the Heart.—With each contraction of the heart about 112 grams (4 ounces) of blood is discharged from each ventricle and forced to the lungs and the various organs of the body. A heart beating seventy times a minute has thus forced into the vessels of circulation about 7.8 kilograms (17.5 pounds) of blood during this short period of time. If the amount be computed for a week, month, or year, the volume becomes enormous. In a person living to be forty years of age the heart has contracted nearly fifteen hundred millions of times, and the volume of blood thrown out by this little organ would weigh about 150,000 metric tons (or somewhat more than that number of English tons). These figures are simply astounding! This wonderful organ, of which poets have sung, is, after all, only a pump. This "seat of courage," this "abiding place of faith and love," this "home of the soul," is but the

hardest-working organ of the whole body. Yet within its substance there is the greatest of all mysteries—that of life. Its labor is never finished, and it goes on with perfect rhythm, rebuilding its damaged walls, supplying its own lubricant, without interruption or cessation, as no other piece of mechanical apparatus is capable of doing.

106. Circulation in the Arteries.—The arteries may be looked upon as a system of branching, elastic tubes leading to all parts of the body. The area of arterial surface is greatly increased by this branching process, and the shock produced upon the arterial walls by the sudden contraction of the ventricles becomes less as the vessels lessen in size and their walls diminish in thickness. The continual action of the heart keeps the elastic fibers in the walls of the vessels constantly on the stretch, and produces a condition in the vessels known as *arterial tension.* This is necessary for the constant and steady flow of the blood through the minute arteries and capillaries.

107. The Pulse.—With each contraction of the ventricles of the heart, an impulse or wave is sent outward from the heart along the arteries. This wave-like motion, which may be felt in various parts of the body, is commonly known as the pulse. The vessels increase somewhat in size and are thrust a trifle forward, giving a distinct impulse to the finger when placed upon the artery. This effect may be seen in the vessels which lie near the surface. Every one is familiar with the pulse at the wrist, the throbbing of the large vessels in the neck, or the beating of the artery in the temple. If the ear be held to the chest-wall in the cardiac region, and a finger be placed upon the radial artery of the wrist, it may be noted that there is a short period of time between the heart-sounds and the pulse-beat. This period would

be wanting if the arteries were rigid, inelastic tubes, but because of this elasticity, the great vessels are first put upon the stretch ; this distension is quickly followed by a contraction which sends a wave along the entire length of the branches given off from the main trunk. The time between the contraction of the heart and the pulse-beat at the wrist is the time it takes this wave-like motion to travel from the heart to the wrist. The pulse decreases in force as the distance from the heart increases, until it is lost in the minute arteries at the beginning of the capillaries. The pulse is well shown when an artery

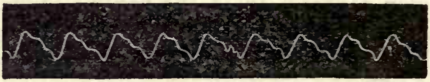

FIG. 68—Trace of the radial pulse (normal) taken by the sphygmograph.

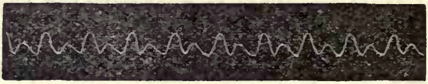

FIG. 68*a*.—Pulse of typhoid fever.

is divided. Because of the arterial tension, blood is thrown from a cut or ruptured artery in a jet, and with each impulse of the heart the jet is increased in height, to fall again while the heart is at rest. A delicate instrument, known as the sphygmograph, has been invented which shows the difference between the pulse of health and that of disease. (Figs. 68 and 68*a*.) The tracings made by this instrument show an abrupt rise due to the contraction of the ventricles, followed by a gradual fall. The slight impulse noted during the fall of the arterial tension is probably due to the sudden closure of the semi-lunar valves which guard the openings of the pulmonary artery and aorta.

108. Circulation in the Capillaries.—When the blood has passed through the various divisions of the arteries to the capillaries, the wave-like motion or pulse has become obliterated, and the flow of the blood through these channels is uniform and steady.

If the web of a frog's foot be examined through a microscope, the blood-globules may be seen shooting along these minute vessels, rolling over and over and catching upon the angles made by the division of the capillaries. (Fig. 69.) Here and there, a white globule may pass slowly along. It nearly fills the caliber of the vessel and clings to its sides as it is forced forward by the blood-current. If the web be pricked or irritated, the walls of the capillaries near the injured part dilate, and the globules, both red and white, hurry to the injured part for the purpose of repairing the damage done. It is in the capillary system that the blood yields its nutritive principles to the tissues, and receives the waste matter thrown off during life.

FIG. 69.—Capillary circulation in web of frog's foot.

109. Circulation through the Veins.—After the blood has found its way through the capillaries it enters the small veins, and, through this system of vessels, finds its way back to the heart. The flow is always towards the heart, for the valves, which are found at frequent intervals along the course of these vessels, prevent any return of the blood to the capillaries. There are three causes for the onward flow of the blood in the veins: the pressure from behind, or impetus which is given to the

blood by the action of the heart; muscular contraction, which compresses the thin walls of the vessels which pass through or about the muscles; and the inspiration of air into the lungs. By expanding the chest, the blood in the large vessels near the heart is drawn towards this central organ with as much force as is required to fill the lungs with air.

110. Rapidity of Circulation.—Experiments have been made on the lower animals that show the rate at which the blood moves through the blood-vessels. Generally speaking, the larger the animal the longer it takes for the blood to complete the circuit. About twenty-eight heart-beats are required to force the blood on one round of circulation. Large animals require more time than small ones, because of the size and the slow action of the heart. In man the circuit is completed in about twenty seconds, though this varies with the rapidity of the heart's action. The blood moves fastest in the arterial system and slowest in the capillaries. The capillaries possess about three hundred times more area than the arteries, and the movement of the blood is necessarily much slower. The veins have a little more than double the area of the arteries, and the blood in them moves more slowly than it does in the arteries, but more rapidly than in the capillaries.

111. Injuries to the Blood-Vessels.—If the character of the blood-vessels be borne in mind, together with the flow of blood in each, it becomes an easy matter to determine the kind of vessel injured when the tissues are cut or lacerated. The arteries throw a jet of bright red blood, and show a distinct impulse with each heart-beat. The capillaries present a bleeding surface from which the blood slowly oozes. The veins give forth a steady stream of dark purple blood. Bleeding from the capillaries and veins is easily controlled,

unless the injury is very extensive, the removal of all pressure between the injury and the heart being all that is necessary. With the arteries it is very different. Because of the pressure in these vessels (arterial tension) the injured ends are kept wide open. To control hemorrhage from an artery, pressure should be made over the course of the vessel between the point of injury and the heart. The fingers may be pressed tightly over the artery, or, if the injury be to the arm or leg, the limb may be corded tightly above the bleeding-point.

112. Effects of Alcohol on the Circulation.—Alcohol, introduced into the circulation in quantities that are not overwhelmingly poisonous, increases the rapidity of the heart's action and raises the pressure in the arterial system. If the alcohol be increased beyond a certain amount, the effect is entirely opposite; the heart beats more slowly, and the arterial tension falls below the normal standard. If the quantity be still farther increased until the amount becomes fatal, the action becomes gradually slower until it finally ceases. Experiments show that these effects are due to the local action of the alcohol on the heart-muscle, and not to paralysis of the nerves which supply the organs of circulation. Alcohol circulates in the blood in an unchanged condition, and stimulates, or rather irritates, the fibers of the heart, as the prick of a sharp instrument or as an acid solution excites the excised heart of the frog. As the heart of the frog becomes tired after a little time, so the living heart feels the effect of this increased activity. Small quantities of alcohol stimulate, while large quantities depress and destroy muscular activity.

The action of opium on the heart is much the same as that of alcohol. Small quantities stimulate, while large amounts depress. The presence of alcohol in the blood

hastens coagulation and diminishes its power to yield its oxygen to the tissues. Alcohol causes a separation of the coloring matter from the corpuscles, and the microscope shows a shriveling of the globules and a deposit of yellowish matter in their interiors. The use of alcohol, when the system is in a healthy condition, greatly increases the work done by the heart, and, by shortening its period of rest and recuperation, injures the quality of the muscular fibers.

"Alcohol acts most perniciously upon the red corpuscles by dissolving the iron and devitalizing them. Drs. Virchow and Boecker agree that 'alcohol poisons the blood, arrests development, and hastens the decay of the red corpuscles, there being also a loss of power, by a decrease of the vitality in the blood disks, to become red when exposed to the air in the lungs, as well as changing the red blood to purple.'"—Dr. William Hargraves.

"Alcohol diminishes the power of the red corpuscles to transmit oxygen to the tissues."—J. H. Kellogg, M.D.

"In Munich, where the average amount of beer consumed reaches 565 litres per capita, not only is heart-disease very prevalent, but the duration of life among those engaged in the brewing trade is very much less than that attained by those not so engaged."—*Journal of the American Medical Association.*

"An alcoholic heart loses its contractile and resisting power, both through morbid changes in its nerve-ganglia and in its muscle-fibers. 'If the habitual use of alcohol causes the loss of contractile and resisting power by the impairment of both the nerve-ganglia and muscle-fibers of the heart, how can it act as a heart-tonic?'"—Dr. Alfred L. Loomis.

"Alcohol from the stomach quickly reaches the blood, and by it is brought into direct and pernicious contact

with the living tissues of the body."—*American Medical Quarterly.*

"The introduction of alcohol into healthy blood can do nothing but mischief. No one who is familiar with the action of poisons upon the living animal body has the smallest hesitation in saying that alcohol is a poison." —Dr. W. B. Carpenter, London.

"In the ordinary use of alcoholic drinks, enough alcohol is not taken to produce death by coagulation of the albumen of the blood; but this affords no warrant for assuming that the lesser quantity is neutral or inactive. . . . Just to the extent in which it is present it must exert an unhealthy, abnormal influence upon albumen." —Professor Youmans.

"Excessive alcoholic indulgence injures the walls and valves of this organ (the heart), and deranges and dilates the caliber of the larger blood-vessels."—*Journal of Nervous and Mental Diseases.*

QUESTIONS ON THE CIRCULATION.

1. Of what importance is the heart?
2. Give a general description of the heart.
3. Explain its division into chambers.
4. What blood-vessels empty into each auricle?
5. What can you say of the structure of the different chambers of the heart?
6. Describe the valves of the heart.
7. Draw diagrams illustrating the chambers and valves.
8. What openings lead from the ventricles, and how are these openings guarded?
9. How do the two parts of the heart act?
10. What are the blood-vessels?
11. Describe the structure of the arteries.
12. Define the pulmonary artery; the aorta.
13. Describe the capillaries.
14. What is the structure of the veins?
15. Illustrate the valves of the veins.

16. What is the blood?
17. What is its composition?
18. Describe the two kinds of corpuscles.
19. What is the amœboid movement?
20. What is the composition of the plasma?
21. What is meant by coagulation?
22. What is its purpose?
23. What is the amount of blood in the body of an average man?
24. What is meant by the circulation of the blood?
25. Draw diagrams illustrating the course of the blood through the heart.
26. What are the sounds of the heart?
27. Why does not the heart wear out?
28. What is said of the amount of work done by the heart?
29. What is meant by the arterial tension?
30. What is the pulse?
31. Do the pulse-beat and the heart-sound exactly correspond? Why?
32. What change takes place in the blood while in the capillaries?
33. What causes the onward flow of blood in the veins?
34. How does circulation in the capillaries differ from that in the arteries?
35. How long does it take the blood to make one circuit?
36. When the tissues are cut, how may the kind of blood-vessel injured be determined?
37. How may bleeding be controlled?
38. What are the effects of alcohol on the heart?
39. What is the action of opium on the heart?
40. How is the blood affected by alcohol?

EXPERIMENTS ON BLOOD AND CIRCULATION.

Experiment 1.—A string may be wound around the middle of the last joint of the finger, and when it has become swollen and darker colored, a slight prick with a needle will cause a drop of blood to exude. This may be placed upon the slide of a microscope and covered gently with a strip of thin glass so as to spread it out. Two other drops may be covered with a wine-glass having a bit of wet blotting-paper or sponge inside to keep them from drying. To one of these drops a few grains of common salt

may be added. The first drop, on examination with the microscope, or even with a hand-lens, will show the plasma and corpuscles of the blood; the second drop will illustrate the coagulation of the blood; and the third will prove that this property of coagulation may be arrested by artificial means, such as the addition of the grains of salt.

EXPERIMENT 2.—A microscope-slide of heavy glass is manufactured having in it two depressions connected by a hair-like channel. A drop of blood may be put into one of these hollows and the whole covered with a very thin glass (a scale of mica will answer the purpose). When this is put under the microscope and very slight pressure applied with the finger over the hollow containing the blood, it will run through the channel to the other hollow, and the red and white corpuscles may be plainly seen flowing through the channel.

EXPERIMENT 3.—To examine the circulation in a frog's foot carefully attach strings to two of the toes and gently stretch the membrane over a glass microscope-slide. The frog, with the exception of the foot to be examined, should be wrapped in a wet cloth. The membrane should be kept in a moist condition, and the leg in as natural a position as possible.

EXPERIMENT 4.—To illustrate the action of the auriculo-ventricular valves of the heart, secure a heart that has been carefully removed by a butcher from some animal. It should be free from all cuts and incisions, and should have attached considerable portions of the large vessels, *i.e.*, the aorta and the pulmonary veins and arteries. Upon one end of a glass tube of proper size draw a segment of rubber tubing, covering the glass an inch or two from the end; insert this rubber-covered end in turn into the arteries and veins, tightly binding their free ends to the tube. Hold the tube in a vertical position and fill with water (pressure greater than that caused by the weight of the water may be exerted by blowing into the upper end of the tube). If a tube be thus inserted into the free end of the aorta, giving the flow of water a direction opposite to that of the blood, it will be found that comparatively little can be forced past the bicuspid valve into the left auricle. A change of direction made by inserting the tube into the pulmonary vein will give a copious flow from the aorta. The experiment may be carried as far as desired.

CHAPTER XII.

RESPIRATION.

113. Respiration.—Respiration is the process by which oxygen is introduced into the system. It is the most constant phenomenon of life both in animals and vegetables, and without it life is impossible. The minutest blade of grass, the tiniest leaf takes into its organism oxygen from the air around it. The lowest form of animal life, such as the amœba of ponds and ditches, absorbs this same gas held in solution in the water in which it lives. As we pass up the scale of organized beings, we find a well-marked respiratory apparatus until, in the warm-blooded animals, the apparatus is found in perfection.

114. Organs of Respiration.—Three things are essential in a respiratory apparatus, viz.: a moist, permeable membrane; a circulating fluid on one side; and air, or an aërated fluid, on the other. In reptiles and other cold-blooded animals respiration is less active and the respiratory organs are simple. In fishes the breathing is accomplished by means of gills. The *menobranchus* is supplied with feathery tufts of mucous membrane on the sides of its head through which the blood circulates, and these tufts are moved to and fro in the water. In the salamander and newt is found a sac, or bag, into which air is drawn, and regurgitated after the oxygen has been wholly or partially absorbed. In frogs and reptiles these sacs are divided into cells or chambers by folds or partitions of the membrane which lines the sacs, thus

increasing the absorbing surface. The lungs of warm-blooded animals do not differ essentially from these sacs. If the lung of a frog could be divided and subdivided into innumerable little cells or air-chambers (Fig. 70) by thin folds of the mucous membrane which lines the cavity, its construction would correspond closely to that of the lungs of man.

FIG. 70.—Section of air-cells: *a*, two lobuli; *b*, air-vesicles; *c*, terminal bronchial tubes.

115. The Chest-Cavity.—The chest-cavity is filled by the heart and lungs. (Fig. 71.) The lungs (two in number) are somewhat conical in shape, and will float when thrown into water, because of the air contained in the air-cells. The outer surface is covered with a smooth, shining membrane called the pleura. The inner surfaces of the walls of the chest are covered with a similar layer.

The pleura, like the pericardium, secretes its own lubricant, so that the lungs move easily in the chest-cavity during the movements of respiration. (Fig. 71.) In the thin partitions which divide the lungs into thousands of little air-cells, are found the capillary blood-vessels of the lungs. Air finds its way into the air-cells through the trachea, or wind-pipe, and the bronchial tubes. The trachea passes down the front of the neck from the larynx to a point nearly opposite the attachment of the second rib to the sternum. Here it bifurcates, forming the right and left bronchial tubes, and these in turn divide and subdivide and pass to all parts of the lungs.

The trachea is about 2 centimeters ($\frac{4}{5}$ of an inch) in diameter. The smallest bronchial tubes are but a millimeter ($\frac{1}{25}$ of an inch) in diameter. These terminal bronchi open into a group or cluster of the minute air-cells which form the substance of the lungs. (Fig. 70.) This system of tubes is composed of cartilaginous rings held together by connective-tissue fibers and lined with a layer of mucous membrane.

This membrane is covered with a layer of cili-

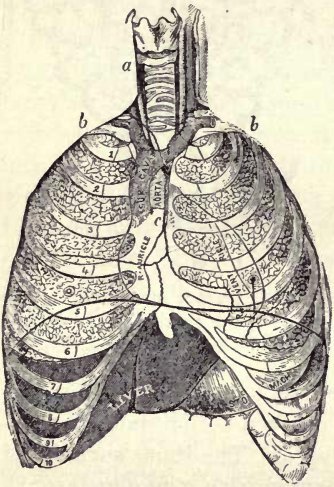

Fig. 71.—The position of the respiratory organs and their relation to other organs : *a*, trachea ; *bb*, clavicles ; 1–10, ribs ; lungs enclosed within the ribs ; *c*, sternum.

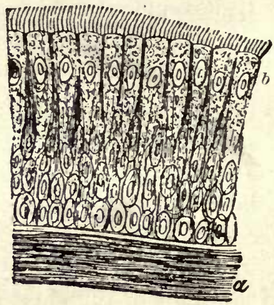

Fig. 72.—Ciliated epithelial cells highly magnified: *a*, innermost layers of the mucous membrane; *b*, superficial cells bearing cilia.

ated epithelial cells, *i.e.*, cells whose free surfaces are covered with fine, hair-like processes. (Fig. 72.)

These little processes always wave in the same direction, from within outward, and foreign substances, such as dust, the pollen of plants, or any impurities which may be taken in with the inspired air, are forced away from the delicate lung-tissue.

116. The Larynx.—At the upper end of the trachea

is a peculiar cartilaginous structure called the larynx. (Fig. 73.) In its interior are the organs of speech, or vocal cords.

117. Movements of Respiration.—Respiration consists of two separate acts or processes—*inspiration,* or

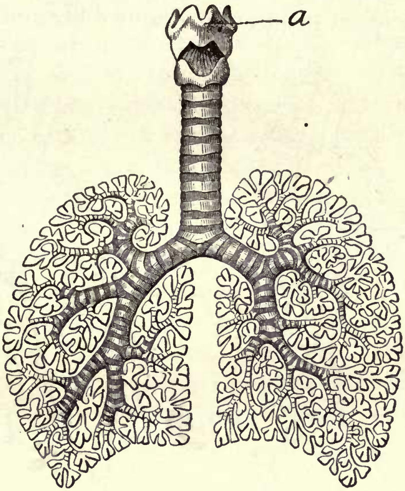

Fig. 73.—The larynx, trachea, and bronchi: *a*, the thyroid cartilage or "Adam's apple."

the taking of the air into the lungs; and *expiration,* or the exhaling of the inspired air.

118. Inspiration is an active process, and the muscles of inspiration are brought fully into play. The ribs are drawn upward and outward, increasing the transverse diameter of the chest.

The sternum is raised a trifle and is thrust slightly forward, increasing the thickness of the thorax.

The diaphragm, which is a thin, sheet-like muscle, rising in the form of a dome from its attachment to the lower margin of the chest-wall, contracts and its center

is drawn down, thus increasing the perpendicular axis of the thoracic cavity. (Fig. 74.) In this way the chest-cavity is increased about .5 of a cubic decimeter (30 cubic inches).

119. Expiration is, generally speaking, a passive process. Little or no muscular power is used.

The muscles of inspiration simply relax and the chest-

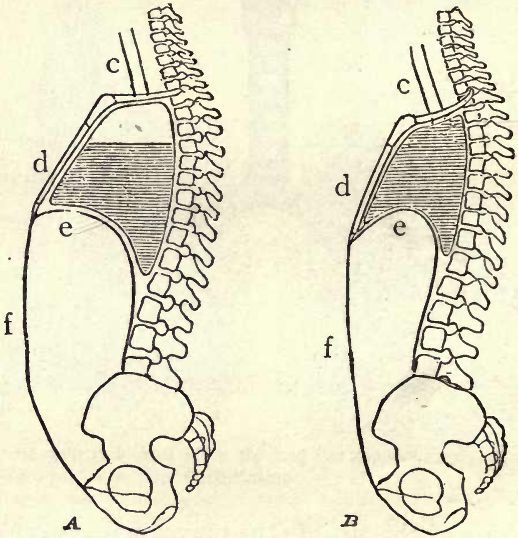

FIG. 74.—Diagrams showing sections of the body, in *A*, inspiration; *B*, expiration: *c*, trachea; *d*, sternum; *e*, diaphragm; *f*, abdominal walls.

walls return to their former position. The muscles of expiration, however, are well developed, and are called into action when the breathing is rapid and labored or when a person plays upon a wind-instrument.

The capacity of the thorax may be greatly increased by the daily practice of inhaling to the fullest capacity of the lungs several times in succession. The shoulders should be thrown well back, the air drawn into the lungs,

and when the chest is fully expanded, the breath may be held for a few seconds.

In this way the circumference of the chest may be increased, from full expiration to full inspiration, a decimeter (4 inches) or more, sometimes 1.5 decimeters (6 inches), the normal expansion being about .5 of a decimeter (2 inches).

120. Frequency of Respiration.—When the body is in a state of rest, respiration goes on at a rate of twelve to twenty times a minute. During vigorous exercise this number of respirations is greatly increased. The heart beats faster, more blood is sent to the lungs, and more air is required for its purification. The process of breathing goes on without any attention on our part, yet we are able to control the operation to a certain extent. We may increase or decrease the rapidity of respiration at will, or we may stop the process altogether for some seconds. This should be remembered if one is obliged to pass through smoke or poisonous gases. Several deep breaths should be taken to change the air in the lungs thoroughly, and then the breath should be held as long as possible. Pearl-divers become proficient in holding the breath, and can remain under water three or four minutes.

121. Capacity.—The lungs are not filled and emptied with each respiration. A small part only of the air in the chest-cavity can be expelled when the chest is contracted to its smallest extent. The lungs when expanded contain about 5 cubic decimeters (somewhat more than 300 cubic inches) of air, and from ten to twelve deep respirations are required to change this quantity completely. It is thus seen that there is a large reserve which can be used during violent exercise. People live a long time, and live very comfortably, with but one lung, if physical labor is not required.

122. Changes in the Air from Respiration.—The air we breathe is changed to a considerable extent by the respiratory process. The atmosphere, which is everywhere about us, is composed of about seventy-nine parts of nitrogen (N) and twenty-one parts of oxygen (O). There is also a small amount of carbon dioxid (CO_2) always present, together with a varying amount of moisture and dust. The volume of air expelled from the lungs with each expiration is about equal in amount to that taken in, but examination shows that the quantity of oxygen in the respired air has diminished about five per cent. Five per cent. of the life-sustaining element has been taken from the air during its stay in the lungs, and in its place is found nearly an equal amount of carbon dioxid. When air has been breathed over and over, and there is no fresh supply, it becomes incapable of supporting life. Even when the carbon dioxid and other impurities are removed, warm-blooded animals die if the oxygen in the air be reduced to ten per cent. of its original volume.

123. Carbon Dioxid.—The carbon dioxid which is exhaled from the lungs is the product of the tissue-changes going on in the body.

This gas, which is a union of one atom of carbon and two atoms of oxygen, is one of the products of combustion, fermentation, and putrefaction. Wherever one of these processes is going on this gas is found in greater or smaller quantities.

It is incapable of supporting life, for it will not give up its oxygen when taken into the lungs, and death is produced by suffocation.

124. Moisture and Animal Matter.—The moisture which is thrown off with the respired air comes from the mucous membrane lining the air-passages. The vapor thus exhaled can be seen in the air on cold mornings.

It is this moisture which collects on the panes of sleeping-room windows.

If this moisture be collected and closely examined, it is found to contain a small amount of animal matter.

It is this substance which gives the faint odor to the breath. In animals it is much more noticeable than in human beings.

In crowded rooms, where ventilation is imperfect, this odor becomes very apparent to one coming in from the fresh air, and when these rooms are tightly closed for a time the odor which comes from this decomposing matter is very offensive and unwholesome.

125. Changes in the Blood during Respiration.—The venous blood, as it flows from the tissues of the body to the heart, is of a dark purple color, or nearly black. After passing from the right side of the heart through the capillary network of the lungs it loses its dark color and becomes a bright scarlet. This change of color will not take place if oxygen is not allowed to enter the lungs. Animals deprived of oxygen show signs of distress, and in a short time die from suffocation. If the blood be examined after death, the arterial blood, which is usually of a bright scarlet color, is found to be dark, like the venous blood, and to contain the same ingredients. If venous and arterial blood be analyzed, the former is found to contain considerable carbon dioxid, while the latter is rich in oxygen. The blood, therefore, in its passage through the lungs, gives up part of its carbon dioxid, takes to itself oxygen, and changes color. This passage of carbon dioxid from the blood and of oxygen to the blood is known as the *interchange of gases.* This change will take place outside the body, if venous blood be placed in a jar of oxygen, or agitated in the open air. If a bladder be filled with venous blood and suspended in oxygen, the blood will

lose its carbon dioxid and absorb the oxygen through the walls of the bladder. In the living tissues this process is much more rapid and complete than in this crude experiment.

The changes in the blood during its passage through the lungs may be summed up as follows: carbon dioxid, moisture, and a small amount of animal matter find their way through the walls of the lungs and blood-vessels, and pass off with the expired air; the oxygen of the air passes into the blood-vessels and enters into loose chemical combination with the hemoglobin, changing venous blood to a bright scarlet.

126. Effects of Vitiated Air.—It has been estimated that about 360 cubic decimeters (13 cubic feet nearly) of air are taken into the lungs each hour, or 8,640 cubic decimeters (somewhat more than 300 cubic feet) in the twenty-four hours. About five per cent. of the oxygen contained in this volume of air is taken up by the blood during its passage through the capillaries of the lungs, and nearly an equal amount of carbon dioxid is exhaled with the expired air. With the carbon dioxid is a small amount of moisture containing minute particles of animal matter. When these substances are exhaled in the open air, they rise quickly because of the warmth imparted to them, and are carried away by aërial currents.

If the air is confined, and a person is compelled to breathe it over and over until a large amount of carbon dioxid is present, a sense of drowsiness and indifference is experienced. The oxygen of the air is being slowly exhausted, and its place is being taken by the impurities thrown off from the body. Air in which this gas is present to the amount of twenty per cent. is incapable of supporting life. Air which contains more than .07 per cent. of carbon dioxid, produced by the respiratory

process, is considered by sanitarians to be unfit for respiration. Air containing two per cent. of manufactured carbon dioxid may be breathed with impunity, but when the animal effluvia which is exhaled in breathing is present, a fraction of one per cent. of carbon dioxid renders the air unfit for use. Many instances can be cited from history, of people who were crowded into close and poorly ventilated rooms, who became unconscious and died from the effects of the changes produced in the air. The effect of vitiated air is often seen in theaters and lecture-rooms. People become drowsy and lose interest in what is being said and done. It becomes almost impossible to control the faculties and give close attention. The mind does not work quickly, and reasoning becomes difficult. People who sleep in poorly ventilated rooms are apt to wake with a dull headache. They are not refreshed by the night's rest, and have to meet the labors of the day with diminished vital powers. Hence our sleeping-rooms should be large, and the air should be changed frequently. In sick-rooms great care should be taken to have the air pure, as the breath of sick people contains more impurities than that of persons in health. Offices and school-rooms should receive special attention, that the blood may receive its full supply of oxygen, and the faculties be kept at their best.

127. Sources of Carbon Dioxid.—There is always present in the air a small amount of carbon dioxid. The air of cities has a larger percentage than the air of the country. The air on top of a high mountain is freer from this gas than the air at its base.

Generally speaking, this gas is the result of the process of oxidation. The oxygen of the air unites with the carbon in the substance acted upon, and is given off in the form of carbon dioxid. Combustion is rapid

oxidation, and carbon dioxid passes off in considerable quantities with the smoke. When illuminating gas or a lamp is lighted in a room the air becomes more or less charged with the gas. The decay of wood and of vegetable matter is a process of slow oxidation. Putrefaction and fermentation are also forms of the same process, and wherever one of them is in progress carbon dioxid is one of the products.

This gas is also found in large quantities in volcanic regions. It is heavier than the air, and, if the aërial currents are not strong enough to carry it away, it may settle in low places in sufficient quantities to produce death, if persons or animals attempt to traverse these places. In coal-mines this gas, known as "choke-damp," gave great trouble before ventilation was so thoroughly understood. The carbon dioxid which comes from the lungs with the exhaled air is also due to a process of oxidation which goes on in the tissues of the body. The oxygen of the air is taken up by the red coloring matter of the blood and is carried to all parts of the system. It passes through the thin walls of the capillaries to the tissues, and finally re-enters the blood in combination with carbon, and is thrown off from the system through the lungs.

128. Purification of the Atmosphere.—If some means did not exist whereby the carbon dioxid, which is constantly forming in large quantities, could be disposed of, the whole atmosphere would become charged to such an extent that life would be impossible. Although this gas is heavier than air, it very seldom accumulates in quantities sufficient to do harm. The air is in constant motion, and all poisonous gases are quickly carried from their sources, and diffused in the great aërial ocean that envelops the earth. Gases are themselves diffusible, and according to a known law mingle thor-

oughly when brought in contact with each other. In this way the carbon dioxid becomes thoroughly mixed with the air about us. Nature has further provided for a complete renovation of the atmosphere. The plant-life which everywhere exists during some season of the year is the agency whereby this change is accomplished. Every growing plant has the power of taking into its organism the carbon dioxid ever present in the air. The carbon in the gas is seized upon and enters into the composition of the plants, and the oxygen is set free to enter again into combination with oxidizable substances.

Like changes are constantly taking place in the ocean. The vegetable growths absorb the carbon dioxid which the fish and other animals are constantly throwing off, and the oxygen is set free to be breathed again by the finny inhabitants.

In this way the purity of the atmosphere is constantly maintained, and, except in volcanic regions, or in the vicinity of large cities, the percentage of oxygen and carbon dioxid in the air remains unchanged.

129. Alcohol, Opium, Tobacco.—Alcohol, opium, tobacco, and many other drugs of like nature have a direct action upon the nerve-centers of respiration, the result of which is a diminution of the amount of air taken into the lungs. When enough of these substances is introduced into the system to produce an effect, the respirations become less frequent ; or, if the number per minute be unchanged or increased, they are shallower, and less air is drawn into the lungs. When the quantity taken is fatal, the centers of respiration finally cease to act and respiration stops, though the heart may still continue to beat. These drugs impart their peculiar odor to the breath, for some of their substance is thrown off from the body through the lungs. Alcohol and opium seem to have some influence over the tissue-changes

which take place in the body. The amount of carbon dioxid exhaled is lessened, and the system does not use so much oxygen.

"Cases of lung diseases are aggravated by the use of tobacco. Consumptives need pure air; tobacco-smoke makes the air impure. In bronchial trouble tobacco-smoke aggravates the cough; it acts as an irritant to the already irritated surface of the bronchial tube."—Dr. B. W. Richardson, in *Diseases of Modern Life.*

"Among the agencies which act powerfully in causing consumption are damp dwellings, and workshops, over-crowding, defective ventilation, occupations which involve the inhaling of irritating dust, and alcoholic excess."—*The Lancet.*

"As regards the respiratory system, there is increased liability to bronchial catarrh in those who take much alcohol."—R. Hingston Fox, M.D.

"An irritated and inflamed condition of the throat, often extending to the tubes of the lungs, is a common occurrence in free drinkers."—Dr. A. B. Palmer, late Professor of Pathology in the University of Michigan.

"Nothing in pathology is more evident than the fact that alcohol is a prolific source of pulmonary disease; nothing in toxicology better established than the observation of the action exerted by alcohol upon the respiratory center. For this reason it is especially dangerous in pulmonary consumption."—Dr. Woodbury.

"Alcohol, even in small quantities, acts on the nerve-pabulum in the blood, preventing it from taking up oxygen and exhaling carbonic acid. . . . Every breath we draw, every movement we perform, every thought we think, is but the outcome of the transformation of matter under the influence of oxygen."—Dr. George Harley.

"Alcohol tends to injure the lung-tissues, and may

cause a serious disease of the lungs."—*School Physiology Journal.*

"Excessive smoking is one of the chief factors of disease in the male sex. Indeed, no habitual smoker can be truly said to be well, for the habit inflicts injury upon the stomach, brain, heart, blood, nerves, mouth, and lungs, besides being a primary or secondary cause of various specific diseases. Its effects upon the young are most deplorable and disastrous. I would entreat every youth who has not yet learned this habit to avoid it as he hopes for bright health and unclouded intellect."—Dr. Drysdale.

"The lungs need all the oxygen they can get in the air drawn into them, and if the boys will apply their own knowledge of physiology and chemistry, they will see that drawing the breath through fire destroys or prevents much of the oxygen entering the lungs and charges the air with carbon, which is the very thing the lungs are trying to get rid of in the form of carbonic-acid gas. Then the heat dries, sears, and destroys the delicacy of the mucous surfaces and produces cough, bronchial catarrh, ulceration, and often consumption—indirectly, many times, but the prime cause nevertheless."—O. M. Grover, M.D.

CHAPTER XIII.

VENTILATION.

130. Ventilation.—Ventilation is the process by which the impure air of any apartment is removed, and a supply of fresh air is introduced. This is usually effected by opening doors or windows, and the impure air passes out at one opening as the pure outside air finds its way in through the opposite opening. The same result is obtained by opening a single window at top and bottom. The heated air rises and finds its way out at the upper aperture, while pure air passes in at the lower part of the casement. Where houses are not closely built, enough pure air may find its way in through chinks and small apertures, but a thorough ventilation should be resorted to often for the purpose of removing foul odors and such impurities as may have collected.

In rooms where many persons assemble, special apparatus is employed, and in modern dwelling-houses, which are tightly built and are heated with steam or hot water, some special arrangement is often necessary to keep the air pure. It is difficult to find an arrangement which will work automatically and keep the air of dwellings and sleeping-rooms as pure as the outer air. Nearly all contrivances require more or less attention as changes in the temperature occur. It is sometimes necessary to change completely the air of schoolrooms and rooms where many people congregate. To do this the windows and doors may all be opened wide

and the outer air allowed to enter and circulate freely for a few moments. Sleeping-rooms and sick-rooms should receive careful attention. Because the air of a bed-room is cold it is not necessarily pure. Night-air is not harmful and may be allowed to enter freely, if sufficient covering be at hand to keep the body warm.

Sick persons should be supplied freely with pure air. There is little danger of their taking cold, if they are well covered and kept out of all drafts.

131. Vital or Animal Heat.—If we examine inanimate objects about us, we find that their temperature depends upon the temperature of the medium which surrounds them. This is not true of objects possessing life. The lowest forms of plant and animal life have a temperature which is a trifle higher than that of the air or water in which they live. This elevation of temperature above the surrounding medium is known as animal heat or, perhaps better, for plants and vegetables possess this property, vital heat.

132. Plants and Cold-Blooded Animals.—Plants and cold-blooded animals possess this property to a very slight degree, yet the thermometer shows their bodies to be a trifle warmer than the air or water about them. Their temperature also varies with the temperature of the element in which they live. That is, a fish with the water at 5° C. may show a temperature of 5.5°. Now if it be placed in water at 20° C., the heat of the body soon becomes 20.5°. The temperature of hibernating animals also varies much. The more profound the torpor the lower the temperature of the animal.

133. Warm-Blooded Animals. — Warm-blooded animals, independent of surrounding objects, keep a uniform temperature. Changes in the atmosphere affect them very slightly, if at all. The temperature of man is about 37° C., or 98.6° F., and this is maintained,

with but little variation, during summer and winter. As a rule, the greater the activity of the animal the higher the temperature, and the greater the consumption of oxygen. The surface of the body may vary slightly with the changes in temperature, but the inner part keeps a uniform and constant temperature during health.

134. Sources of Heat.—(I.) The primary source of heat is the oxidation of the articles of food taken into the system. The oxygen, which is taken up by the blood during its passage through the lungs, is carried to all parts of the body and unites with the carbon of the food to form carbon dioxid, which is carried to the lungs in the blood and exhaled. This change takes place in the tissues of the body, and is by no means a direct conversion of the food into carbon dioxid, for, as has already been shown, the food taken into the system becomes a part of the living organism, only to be thrown off again during the process of waste and repair. These worn-out food products are thrown off largely as carbon dioxid, the production of which is one of the principal sources of vital heat.

(II.) The various glands of the body also generate heat during their activity. For instance, the blood, during its passage through the liver, gains about half a degree in temperature.

Experiments show that the chemical action which is going on in the various glands of the system is the source of considerable heat. These are known as the chemical sources of heat, because they are the results of the union, in the body of elements or compounds to form new substances.

(III.) Besides these chemical causes there are physical causes. Every movement of the body produces heat. Whenever contraction occurs in a muscle, heat

is produced by the friction of the muscular fibers. Muscular movement also induces more rapid tissue-changes. This fact is demonstrated every day of our lives, if we are called upon to exercise freely or to make unwonted physical exertion. Respiration increases, a larger amount of oxygen is consumed, more carbon dioxid is exhaled, and these processes are accompanied by an increase of heat and a glow of the whole body, with redness of the skin and free perspiration. Mental as well as physical exertion is also a source of heat.

135. Variations of Temperature.—The temperature of the body varies during life. It is somewhat higher in the young than in the aged. There is also a slight daily variation. In individuals the lowest reading of the thermometer is between the hours of two and six in the morning. From this point the temperature rises and reaches its maximum height between five and eight o'clock in the afternoon. These trifling differences, about one degree C., are variations of health and are readily accounted for. In old age heat-production is less active and there is also less physical activity. The daily variations are the result of the active and passive conditions of the body during the day and night.

Beside these variations there is the rise and fall of temperature due to disease and injury. Cases have been noted where the temperature has fallen as low as 19° C. where the vital powers were at a very low ebb, and injury to the spine has been known to cause a temperature of 50° C. These are exceptional cases and are not met with often. A temperature of 41° or 42° C. is quite alarming, and if it remains long at this point death is sure to occur.

136. Regulation of Temperature.—The heat generated in the body passes off largely through the skin. This is accomplished in three ways: by radiation, con-

duction, and evaporation. The air is heated by coming in contact with the skin, and various substances which come in contact with the body, if they are of a lower temperature, gain heat by conduction. Evaporation of the perspiration also lowers the temperature. The blood is also cooled during its passage through the lungs, as is evinced by the fact that the exhaled air is usually warmer than the surrounding atmosphere. In the cold season, we make our own temperature by the use of wraps, which serve to protect the body from the cold air and to retain the heat generated, and by stoves and other kinds of heating apparatus. The body is also able to withstand the effects of extreme heat. Perspiration pours out freely when the temperature of the atmosphere reaches a high point, and evaporation keeps the body cool. In the hot countries the temperature often reaches 50° C., yet the bodily temperature is not raised above the normal.

137. Effects of Alcohol on Vital Heat.—Alcohol, generally speaking, lowers the temperature of the body. If the quantity taken be small, there may be a trifling rise of temperature due to the increased circulation of the blood. This effect is transient, the heat of the body quickly returning to the normal. It is this effect of alcohol in small doses that has given rise to the erroneous belief that a drink of whisky or brandy will "keep out the cold." If the quantity taken be large, there is no rise of temperature, but a decline. In cases of debauch the temperature has been known to fall as low as 24° C. If the quantity taken be sufficient to produce death, the bodily heat diminishes to the end. The idea that spirits of some kind will aid in withstanding long exposure to cold is erroneous. The temperate man will endure longer and greater exposure to cold than the man who takes "grog."

Alcohol also lowers the temperature in some diseases. This has been shown by producing disease in the lower animals and then counteracting the effects of the poison which produced the disease by the administration of alcohol. In the contagious and infectious fevers it lowers the temperature, sustains the heart, and produces quiet and sleep. Its household use for any little illness, a cold, or any ache or pain, is pernicious in the extreme. It should not be used in this way, nor should it be used as a medicine without the advice of a careful physician.

Sir John Richardson, M.D., a member of the English Arctic Expedition, said: "Plenty of food and sound digestion are the best sources of heat."

Dr. Klein states as his experience in the Franco-Prussian war, that the wine supplied in abundance to the French troops only intensified their sufferings from the cold. He says: "Let me tell you that there is nothing that will make you feel the cold more than alcohol."

"The plan of taking alcohol on going out into the cold is a most mistaken one. It may produce a sensation of warmth by dilating the vessels of the skin, and so bathing the cutaneous nerves in a current of warm blood, but in doing so it increases the heat loss."—Fothergill's *Practitioners' Handbook.*

"Those soldiers (during Napoleon's retreat from Moscow) who indulged in the use of intoxicating liquors, sank under the effects of cold almost in battalions; but their fate was not shared by those of their comrades who abstained from those liquors."—Baron Larry, the noted French surgeon.

"Those who habitually take in fresh breath will probably grow up large, strong, ruddy, cheerful, active, clear-headed—fit for their work. Those who habitually take in the breath which has been breathed out by them-

selves or any other living creature, will certainly grow up, if they grow up at all, small, weak, pale, nervous, depressed, unfit for work, and tempted continually to resort to stimulants and become drunkards."—Rev. Charles Kingsley.

QUESTIONS ON RESPIRATION.

1. What is respiration? How general is it?
2. What are the organs of respiration?
3. Describe the chest-cavity.
4. Describe the lungs.
5. Describe the trachea.
6. Describe the larynx and vocal cords.
7. What are the movements of respiration?
8. What can you say of the frequency of respiration?
9. What can you say of the capacity of the lungs?
10. What changes take place in the respired air?
11. What changes take place in the blood during respiration?
12. What are the effects of vitiated air?
13. What are the sources of carbon dioxid?
14. How is the atmosphere purified?
15. What are the effects of alcohol, opium, and tobacco upon respiration?
16. What is ventilation, and how may it be effected?
17. What is vital heat?
18. What differences are there in the vital heat of cold-blooded and warm-blooded animals?
19. How does alcohol affect vital heat?

EXPERIMENTS ON RESPIRATION.

1. Borrow or construct a stethoscope.

2. Get the lungs of a sheep or calf, with the windpipe and heart attached. Note the vocal cords and the cartilaginous rings of the trachea. Dissect out one bronchus, carefully following it to its minute divisions. Examine the air-cells with a microscope. Float some of the tissue in water.

3. Insert a glass tube into the other bronchus, to which attach a piece of rubber tubing. Inflate the lung by means of this, and examine.

4. Construct a glottis and vocal cords, and illustrate their action, by stretching pieces of rubber over the end of a tube and blowing through.

5. The diaphragm of a small animal may be removed by dissection, and preserved in alcohol.

6. Characteristics of the breath may be shown by many simple experiments. Its warmth may be shown by breathing on the bulb of a thermometer; its moisture, by breathing on a mirror. That carbon dioxid is thrown off from the lungs may be proved by breathing into a glass jar for several minutes, and then lowering into it, by means of a wire, a bit of lighted candle. The candle will be extinguished before it reaches the bottom of the jar. Breathe into a bottle of lime-water, and it soon becomes milky in appearance. This is caused by the union of the carbon dioxid of the breath with the lime held in solution, forming carbonate of lime.

CHAPTER XIV.

THE SKIN OR INTEGUMENT.

138. The Skin.—The skin is the outer covering of the body. It is thin, soft, and pliable, yet so strong that considerable force is necessary to tear or break it. It fits so closely that the shapes of the various muscles may be seen, and is so nearly transparent that the dark blue of the superficial veins is very apparent.

139. Structure of the Skin.—The skin is composed of two layers: the epidermis or external layer (also known as the cuticle or scarf-skin), and the *corium* or *derma* (also called the cutis or true skin).

140. The Epidermis.—The epidermis is much the thinner of the two layers, and is made up of flat epithelial cells, one above the other. (Fig. 75.) This outer covering of the true skin is without sensation, and contains no blood-vessels.

Over the parts of the body where there is much wear, as the palms and soles, the epidermis becomes thickened and hard. These "calluses" protect the deep layers of the skin, and may be cut and pricked with impunity.

The outer cells of the epidermis are being constantly shed and worn away by contact with the clothing and other external objects, and their places are taken by new cells, formed next the corium or true skin. At times the outer layer of the skin becomes separated from the deep layer and a blister is formed. A watery fluid collects between the scarf-skin and the true skin, which is finally absorbed, if the external layer be not broken,

and a new epidermis is formed over the corium. In the cells of the epidermis lying next the corium are found small particles of coloring matter, which gives the skin its light or dark color. This pigment gives to the African his dark skin and black eyes and hair. The absence of this coloring matter leaves the transparent skin, colorless eyes, and white hair of the albino.

Fig. 75.—Section of epidermis magnified: *a*, flat epithelial cells; *b*, layer of cells nearest the corium.

141. The Nails and Hair.—The nails and hair are known as appendages of the skin, and are modified forms of the epithelial cells which form the cuticle.

142. The Nail grows from a fold of the cuticle near the end of the finger or toe, and serves as a protection, and on the hand is also of use in picking up small objects. Beneath the nail is the bed, or matrix, from which it grows in thickness. (Fig. 76.) The nail, as it starts from the fold of cuticle near the end of the finger, is thin and somewhat soft. It gains in thickness as it passes over the bed or matrix, and its free margin is quite hard and stiff.

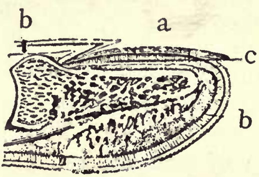

Fig. 76.—Section of nail and parts beneath: *a*, nail; *b–b*, derma; *c*, matrix.

143. The Hair is composed of the epithelial cells of the cuticle, though it is quite different from the nails. Instead of growing from a matrix, its root is enclosed in a sac or pouch known as the hair-follicle. (Fig. 77.) This follicle extends into the deep layers of the skin, and is surrounded by a network of small blood-vessels. It is lined with a thin layer of the epidermis, and at the bottom of the sac is a small projection known as the hair-papilla. The shaft of the hair is formed from the epithelial cells which cover this papilla. The shaft, which is forced from the hair-follicle and grows to considerable length on parts of the body, is composed of an inner portion, which is somewhat soft, and an outer layer of hard, horn-like plates or scales, with overlapping edges. Over the larger part of the body the hairs are fine, and in some places scarcely protrude from the hair-follicles. They increase the surface for evaporation of perspiration, and on the head, where the hair grows thick and long, it serves as a protection from cold, and from blows and falls.

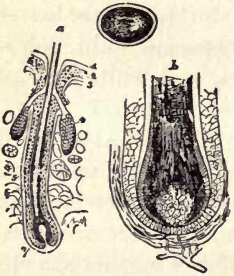

FIG. 77.—Diagrams of the structure of a hair and a hair-follicle highly magnified : *a*, root of hair in the follicle ; 1, cuticle ; 2, true skin ; 3, sebaceous glands opening into the hair-sac ; 4, papilla ; *b*, a larger view of the hair and hair-sac.

There are no hairs on the palms and soles.

144. The Corium, or True Skin.—The corium is much the thicker of the two layers of the skin. In its structure are found blood-vessels and lymphatics, sebaceous follicles, and perspiratory glands. These are surrounded by fibers of connective tissue, which form the framework of the true skin. (Fig. 78.)

145. The Sebaceous Glands.—The sebaceous glands

are minute pouches, or sacs, which secrete an oily substance called *sebum*. They often open into the hair-follicles, and their secretion is discharged upon the hair. On the face they open directly on the surface, and their mouths can be seen.

These openings may become clogged with the secretion from the gland, and minute particles of dirt, becom-

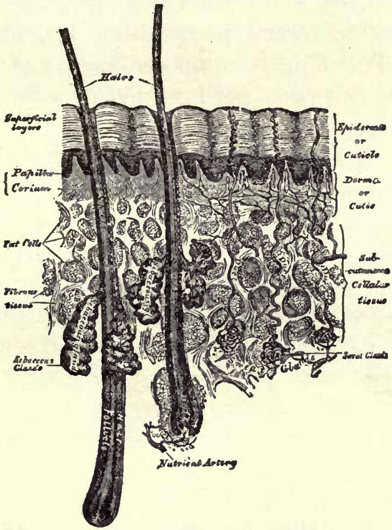

Fig. 78.—Vertical section of the skin magnified.

ing entangled in the mass, give it the appearance of a small black-worm, which can be forced out by pressure. The secretion from these glands furnishes a natural dressing for the hair, and keeps it smooth and glossy; it also keeps the outer layer of the epidermis from becoming hard and rough.

146. The Perspiratory Glands.—The perspiratory glands consist of minute tubes, or ducts, which open on the surface of the epidermis, and extend into the deep

layer of the skin. In the corium, or true skin, these ducts are coiled into little knots, or balls, which are surrounded by a network of minute blood-vessels. (Fig. 78.) If the tube be uncoiled, it measures about 2.5 millimeters ($\frac{1}{10}$ of an inch) in length, and is about .08 of a millimeter ($\frac{1}{300}$ of an inch) in diameter. They number about 480 to the square centimeter (3,000 to the square inch), and from their openings on the surface of the epidermis perspiration is constantly discharged. This fluid is composed largely of water, containing only two parts per hundred of solid matter. It has a salty taste and is acid in reaction.

Much of the perspiration thrown off by these glands is not noticeable. It evaporates as soon as it reaches the surface, and is known as "insensible" perspiration. During exercise, or when the air becomes heated, the flow from the glands is much more abundant. The discharge is then known as "sensible" perspiration, and can be seen on the surface in the form of small drops or beads. When very profuse, it runs from the body in large drops, and may completely saturate the clothing. This flow from the perspiratory glands, and the consequent evaporation, is the chief means of keeping the bodily temperature at a certain point. When the surrounding temperature becomes unusually high, or when the body becomes heated by exercise or work, then these glands become very active. The higher the temperature of the surrounding medium, or the greater the amount of heat produced in the body, the greater the activity of these glands. Because of this, the body is able to bear a high temperature. Persons living near the equator often experience a temperature of 52° C., and frequently it rises several degrees above this point, yet the bodily temperature is not varied, nor is the discomfort great. Workmen in furnaces and foundries work at times when

the heat is very great, but so long as the skin pours forth its secretion the danger of overheating the body is slight. When, from exposure to cold or to drafts of air, the activity of the perspiratory glands is suddenly checked, we say we have "caught cold." There is headache, or a feeling of fullness in the head, a rise of the bodily temperature, and increased activity of the mucous glands of the air-passages. Exposure of this kind should be guarded against, for the consequences are not infrequently serious. Some people take cold much more easily than others, and more than ordinary care should

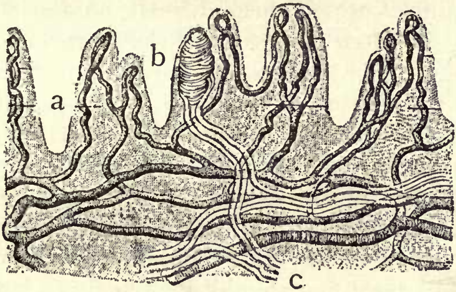

Fig. 79.—Palm of the hand : *a*, looped blood-vessel ; *b*, tactile corpuscle , *c*, nerves.

be taken by such persons to guard against it. Rubbing the skin of the neck and chest with a stiff brush and the use of cold sponge-baths help to toughen the skin and make it less sensitive to sudden changes of temperature.

147. Sensation.—The nerves of sensation are also found in the true skin. These nerve-filaments end in somewhat rounded or elongated bulbs, known as *tactile corpuscles*. They are the organs of touch, and through them we learn the nature of objects about us, whether rough or smooth, hard or soft, blunt or sharp, hot or cold. These little rounded bodies are very numerous in all parts of the skin, especially in the palms and finger-tips. (Fig. 79.) The skin over the ends of the fingers

is the most sensitive of that of any part of the body, except the tip of the tongue.

148. Care of the Skin.—In order that the skin may perform its functions, proper care should be taken to keep it free from all accumulations of the secretions of its various glands. The gray matter from the sebaceous follicles often collects, the solids of the perspiration remain after evaporation, and the dead scales of the epidermis may cling after their usefulness is at an end. When this happens the mouths of the perspiratory glands are apt to become clogged, and the ducts of the sebaceous follicles which open directly on the surface of the skin are often plugged, and the secretions retained. Many times this leads to an imperfect action and an unhealthy condition of the skin. To keep our bodies clean and the pores of the skin well open, baths should be taken often, and frequent airing and changing of underclothing are necessary. A hot bath, with soap and brisk rubbing with a coarse towel, is advisable as often as once a week. This should not be taken directly after a full meal, nor should one remain so long in the water that a feeling of lassitude is produced.

A cold sponge-bath in the morning is invigorating, and is excellent to prevent taking cold; but it is not sufficient to remove greasy deposits or old layers of hard epidermis. Besides the baths already mentioned, there is the shower-bath, used largely by persons who practice in gymnasia, to cool the body and remove perspiration after vigorous exercise. It produces a pleasant reaction and a general sense of comfort and well-being after the body is heated by exercise. Sea and fresh-water bathing are also beneficial if rightly used. The body should not be chilled by remaining too long in the water, and the skin should be rubbed with a coarse towel to bring about a free circulation of the blood when the bath is completed.

The excitement of surf-bathing and the pleasure of fresh-water bathing aid greatly in restoring the energies of the overworked brains and tired bodies of those who are too closely confined, during the greater part of the year, in counting-houses and offices. In olden times, the Greeks and Romans expended large sums of money on public and private baths, and much time was spent in bathing and perfuming the body. While these facilities do not exist at the present day, the means of keeping the body clean are within the reach of every one, and, when rightly used, are a source of comfort and health.

The skin is an index to a person's mode of living. The soggy, thick skin of the gourmand shows the effects of high living and of the use of wine and tobacco. The grimy integument of the tramp tells its tale of neglect; the sallow, pale, uneasy countenance of the morphine-eater speaks of his slavery; and the enlarged blood-vessels in the bloated face of the drunkard are a sign manifest to all. The fairest skin grows coarse under the influence of dissipation, and seems to shadow forth vicious habits and gross appetites.

QUESTIONS ON THE SKIN.

1. Give a brief description of the skin.
2. What is its structure?
3. What is the structure of the epidermis?
4. What causes a blister?
5. What gives the skin its color?
6. How are the nails formed? The hair?
7. What is the structure of the corium?
8. Describe the perspiratory glands.
9. Of what use is perspiration?
10. How do we take cold, and what can be done to prevent it?
11. What can you say of the nerves of the skin?
12. Why is bathing necessary?
13. What can you say of different kinds of baths?
14. Of what is the skin an index?

EXPERIMENTS ON THE SKIN.

1. The hair, nails, and bits of cuticle and scarf-skin may be examined with a microscope.

2. A magnifying-glass should be used in the examination of the skin itself.

The perspiration-pores may be best seen in the palms of the hands.

CHAPTER XV.

EXCRETION.

149. Excretory Organs.—It has been shown that changes are continually going on in the body, and that the system is constantly taking in new material to supply the waste which attends the processes of life.

The lungs dispose of a large part of the waste products, throwing it off during respiration as carbon dioxid.

The skin also aids in disposing of worn-out material through the perspiratory glands. But there yet remains in the system the greater part of the waste substances derived from the proteids of the body.

This portion of waste material, except a part which is thrown off by the glands of the intestines, is disposed of by the kidneys, their construction and blood-supply being especially adapted for this work.

150. The Kidneys.—The kidneys are two in number, and lie in the upper part of the abdominal cavity, one on either side of the spine.

They are bean-shaped, and weigh about 115 grams (4 ounces) each.

The part which corresponds to the eye of the bean is called the *hilum*. At this point blood-vessels find an entrance, and here also is attached the excretory duct (the ureter) which carries the excretions to the bladder. (Fig. 80.)

A longitudinal section through the eye of the kidney shows that organ to be composed of two forms of structure: an outer layer, or cortex, and an inner part, the medullary portion. (Fig. 81.)

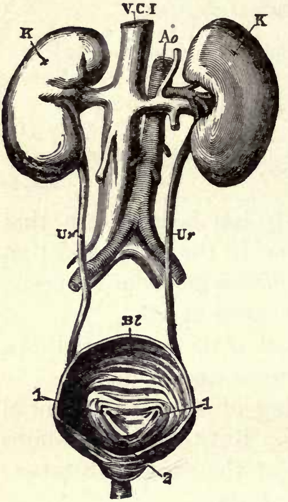

FIG. 80.—The urinary organs: *K*, kidneys; *Ur*, ureters; *Bl*, bladder; *Ao*, aorta; *VCI*, inferior vena cava; 1, opening of the ureters; 2, opening of urethra in the bladder.

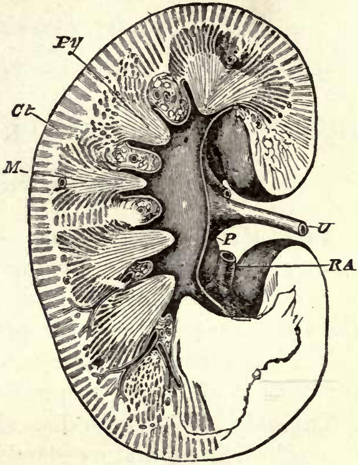

FIG. 81.—Section of kidney: *Ct*, cortex; *M*, medullary layer; *U*, ureter; *RA*, renal artery; *Py*, pyramids; *P*, pelvis.

The cortex is of a deep red color, and is composed chiefly of small rounded bodies (the Malpighian bodies) imbedded in a meshwork of connective tissue.

151. A Malpighian Body.—A Malpighian body is composed of a tuft of small blood-vessels surrounded by a layer of epithelial cells, the whole being encased in what is called the capsule of Bowman.

From each body a duct, or tubule, carries away the matter excreted by it. (Fig. 82.)

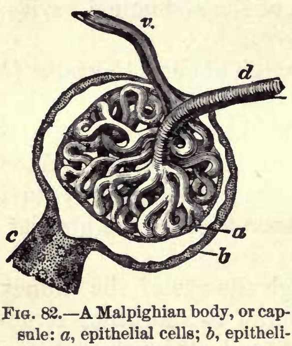

FIG. 82.—A Malpighian body, or capsule: *a*, epithelial cells; *b*, epithelium lining the capsule; *c*, tubule; *d*, small artery; *v*, small vein.

The medullary portion of the kidney is composed of the pyramids of Malpighi, and these pyramids are composed of the ducts given off from the Malpighian bodies.

The pyramids vary in number from ten to eighteen.

They are so arranged that their bases are toward the cortex, and their apices project into the hilum.

The tubes of the pyramids finally unite into several small delivery-tubes which open at the hilum of each kidney.

The cortex is supposed to be the active portion of the

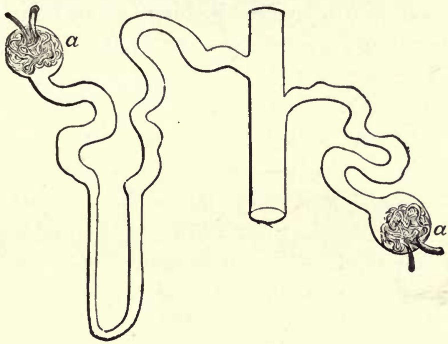

FIG. 83.—One of the tubules of the kidneys magnified: *a–a*, Malpighian bodies.

kidney, yet it is probable that the tubules leading from the Malpighian bodies are also active.

These tubules are at first tortuous or convoluted; then from the cortex (Fig. 83), they form a loop in the medullary portion, become convoluted again, and finally unite in various ways to form a delivery-tube which opens at the apex of a pyramid.

152. The Excretions.—The excretion of the kidneys is composed largely of water, holding in solution substances formed by the destruction of the proteids of the body. These substances are not formed in the kidneys,

but are produced in the tissues of the body, and circulate in the blood ready for excretion.

The kidneys are therefore simply excretory organs, their whole function being to dispose of the worn-out material of the body carried to them by the blood.

About 96 per cent. of the matter excreted by the kidneys is water, and the principal substances held in solution are urea and uric acid. About 30 grams of urea are excreted daily, though this amount varies somewhat according to the diet, being larger if meat, eggs, etc., constitute a large part of the food.

Urea contains nitrogen in large quantities, and when not eliminated from the system causes marked disturbances. Death results in a short time if the kidneys are entirely inactive. There are other substances excreted by the kidneys, such as the phosphates of lime, potash, and soda, also coloring matter and mucus, but the quantities are small and they are of less importance than urea.

153. Alcohol.—The prolonged use of alcohol often brings about in the kidneys changes similar to those produced in the liver.

The kidneys become hardened by a new growth of connective tissue, and the tubules and Malpighian bodies are partially obliterated. These changes occur in some forms of the disease commonly known as Bright's disease, a disease usually progressive and deadly in spite of the best medical treatment and sanitary changes.

"Once the liver is attacked the nitrogenous waste of the body is not carried to the kidneys in proper form for excretion; some is held back, producing a tendency to *gout* and *rheumatism;* the rest is got rid of by extra kidney effort. The usual result is fibrous degeneration of the kidneys, causing one kind of Bright's disease."—H. Newell Martin.

"The majority of beer drinkers die from dropsy, arising from liver and kidney diseases, a direct result of their habits of life."—Dr. Parmlee.

QUESTIONS ON EXCRETION.

1. How are the waste products of the body disposed of ?
2. Describe the kidneys.
3. What does a section through the eye of the kidney show in regard to its internal structure?
4. What is the active portion of the kidney?
5. What is the composition of the excretion of the kidneys?
6. What changes in the kidneys are produced by the use of alcohol?

CHAPTER XVI.

THE NERVOUS SYSTEM.

154. The Vegetative Functions.—The three vital processes which have thus far been considered—digestion, circulation, and respiration—are known as vegetative functions, for they are common to animals and vegetables, each of which takes into its organism substances which aid in the processes of growth, waste, and repair; a circulatory system is common to both, and each takes oxygen into the system, and gives off carbon dioxid. These functions are performed with as great perfection in the vegetable as in the animal kingdom. In each they are vital, and no one of them can be suspended, except for a short time, without injury or death to the plant or animal.

155. Nervous Functions.—Besides these vegetative functions, the higher animals are endowed with higher faculties. Their bodies are so constructed that they are able to move from place to place. The skeleton gives form and stability to the body, the muscles are the motive power, and the nervous system is the controlling agent. Groups of muscles are made to act alone or in harmony with other groups, and the most complicated movements are made with accuracy. Through the nervous system animals also become aware of things external to themselves, and in man it is the seat of still higher faculties: the power to reason and to arrive at definite conclusions; the emotions which influence us in so many of our determinations; and will-

power, which guides our physical movements and controls our moral actions.

156. The Nervous System.—The nervous system is essentially an apparatus of communication. Through it, the sensations, as heat and cold, thirst and hunger, are recognized; the glands are excited to pour forth secretions, and the different parts of the body are made to act in harmony. The brain is the great nerve-center, and here impressions are received and impulses sent forth along nerve-filaments, or fibers, which connect every part of the body with this central mass of nervous tissue.

Thus the nervous system is composed of two distinct structures, fibrous and cellular; the former composed of fibers (Fig. 84) which transmit impressions or nervous impulses, and the latter composed of collections of cells (Fig. 85) or ganglia in which the fibers end.

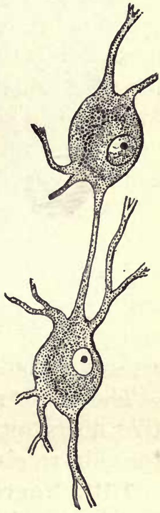

Fig. 85.—Nerve-cells from the human brain.

157. Nerve-Fibers.—The fibers which connect the various parts of the body with the brain are classified in various ways: (I.), according to their source and course, as *cerebro-spinal* and *sympathetic;* (II.), according to their structure as shown by the microscope, as *medullated* or *white,* and *non-medullated* or *gray;* (III.), according to their functions, as *afferent* and *efferent, motor* and *sensory.*

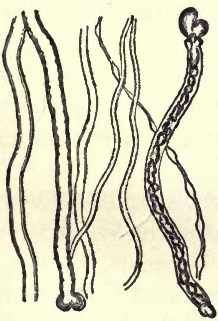

Fig. 84.—Nerve-fibers magnified.

The medullated fibers form the greater part of the white portions of the brain and spinal cord.

These fibers are minute white filaments ranging from 1 to 20 microns ($\frac{1}{25400}$ to $\frac{1}{1270}$) of an inch in diameter.

The non-medullated fibers form the greater portion of the sympathetic nerves.

No difference can be seen in the structure of the nerves which convey impressions to the brain or other nerve-centers, and of those which carry a motor impulse to some muscle. They act simply as connections between the nerve-center and the organs of the body. As in the case of an electric wire, the effect produced depends upon the appliances to which it is attached.

158. Relation of Nerve-Fibers.—In the brain and spinal cord, where large numbers of nerve-fibers are massed together, they form white tracts or bands, the fibers of which are imbedded in a supporting network formed by a substance called neuroglia or nerve-glue.

These white tracts extend along the spinal cord, or connect parts of the brain.

Where the nerves pass from the cavity of the cranium or from the spinal cord, they are in the form of shining white cords held together by a fibrous sheath. These cords pass to the various organs and tissues of the body, and give off branches through which pass motor and sensory impulses.

The motor nerves end in the muscles, and the sensitive fibers terminate in all organs that have sensation, the skin receiving the bulk of these filaments.

159. Nerve-Cells.—If a nerve be traced to its central terminus, it is seen to be continuous with what is known as a nerve-cell.

A nerve-cell is composed of a grayish, granular substance, with a large, distinctly marked nucleus, containing within itself a smaller nucleus or nucleolus. (Fig. 85.)

These cells have an irregular rounded form, with branches or prolongations leading from them.

160. Nerve-Centers.—A collection of these cells is known as a nerve-center (Fig. 86), and in these centers impressions are received through the sensory fibers which lead to them, and motor impulses are sent out through the motor fibers which convey stimuli to the muscles.

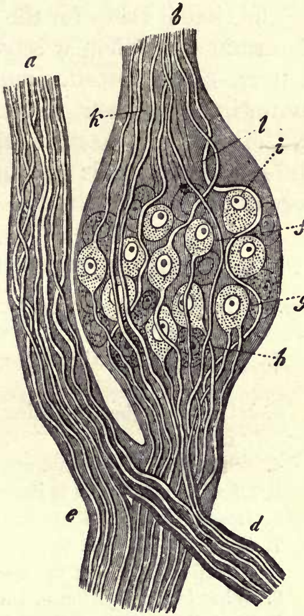

FIG. 86.—A spinal ganglion from a mammal: *a*, a motor root; *b*, a sensory root; *d*, *e*, efferent nervous trunk; *k*, direct, and *l*, tortuous fibers; *f*, unipolar, *g* and *h*, bipolar, *i*, apolar ganglion cells.

161. Rate of Transmission.—By experiments upon men and animals, with instruments of delicate character, the average rate at which impulses travel along the nerves has been found to be about 30 meters (98 feet) per second.

Weak impulses, or such as produce moderate movements, move with as great rapidity as those which cause violent muscular contractions.

Sensory impressions are transmitted with nearly double the velocity of motor impulses. They travel at the rate of about 50 meters (165 feet) per second. Painful impressions move a trifle more rapidly than simple impressions. The rate of transmission varies in different individuals. This is one reason why one person moves more quickly than another. Impressions are

more quickly received in one brain than in another, and the motor impulse is sent forth sooner, and travels with greater rapidity. The rate is not the same in the same individual at all times. It may vary either way from a given rate from one day to another.

The time it takes for the gray cells to act has also been determined. When a sensory impression is carried to a nerve-cell a certain amount of time elapses before a motor impulse is sent forth from the cell. This is known as the time of *sensation* and *volition*. It also varies in different individuals and in the same individual at different times.

QUESTIONS ON THE NERVOUS SYSTEM.

1. What is meant by the vegetative functions? Why are they so called?
2. What is the relation of the nervous system to the skeleton and muscles?
3. Of what higher faculties is the human nervous system the organ?
4. What kind of an apparatus is the nervous system?
5. Of what structures is it composed?
6. How may nerve-fibers be classified?
7. What fibers form the greater part of the brain and spinal cord? What, of the sympathetic nerves?
8. What is the relation of the nerve-fibers?
9. Describe a nerve-cell.
10. What is a nerve-center?
11. What is the rate of transmission of nervous impulses?

CHAPTER XVII.

THE SPINAL CORD.

162. The Spinal Cord.—The spinal cord is contained in the canal of the vertebral column, and extends from the second lumbar vertebra to the base of the brain. (Fig. 87.) It is composed of medullated nerve-fiber and masses of gray cells, which form the nerve-centers of the cord. At intervals nerve-trunks are given off from the cord, which pass out of the vertebral canal and supply the various organs of the body. (Fig. 88.) The cord does not fill the cavity of the vertebral canal, but is surrounded by membranes which encircle it and hold it in position. It is also surrounded by blood-vessels, fat, and connective tissue, which preserve it from shock and jars.

163. Enlargements of the Cord.—At the points where the nerves which supply the upper and lower extremities are given off, the diameter of the cord is increased. These enlargements are known as the *cervical* and *lumbar* enlargements. They are due to an increase in the gray matter at these points, and not to the large number of fibers which are given off. The cord also enlarges after it enters the skull to join the brain, and is here known as the *medulla oblongata*. (Fig. 87.)

164. Arrangement of the White and Gray Matter.—If the cord be cut through transversely, it is seen to be divided nearly into halves by an anterior and posterior fissure. (Fig. 88.) The halves are united by white and gray matter, known respectively as the white

and gray commissures. The white substance of each half is arranged in columns or tracts about the central mass of gray matter. The gray substance in each half is somewhat crescent-shaped, its concavity facing outward. (Fig. 89.)

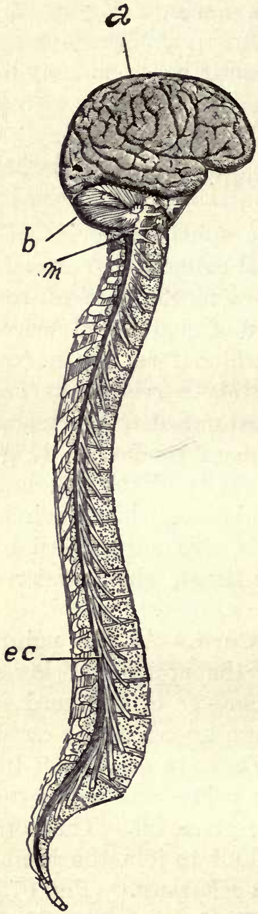

FIG. 87.—Brain and spinal cord: *a*, cerebrum; *b*, cerebellum; *m*, medulla oblongata; *ec*, end of cord.

The columns of the cord are natural divisions made by the shape and arrangement of the gray matter. The two horns of the crescent in each half of the cord divide the white matter of each half into three columns, known as the anterior, lateral, and posterior columns.

165. Union of Nerves and Cord.—The nerve-branches or trunks which are given off from the cord to supply the body are sixty-two in number, thirty-one on each side. Each nerve-trunk has two roots, an anterior and a posterior, which come from the anterior and posterior horns of the gray matter of the cord. (Fig. 90.) The roots from the anterior horn are composed of motor nerves, for galvanism of their fibers produces convulsive movements of the muscles to which these fibers pass. The roots from the posterior horn contain the nerves of sensation, for irritation of these roots produces pain.

166. Results of Experiments.—If an anterior root be cut across, and its distal end galvanized, convulsive movements are produced in the muscles to which its

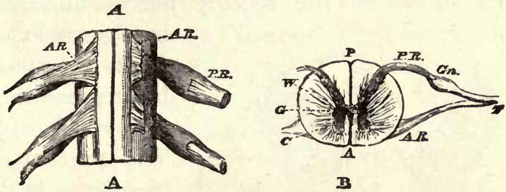

Fig. 88.—*A*. Front view of the spinal cord: *AR*, anterior roots; *PR*, posterior roots. *B*. A cross section of the cord: *A*, anterior fissure; *P*, posterior fissure; *G*, central canal; *C*, gray matter; *W*, white matter; *AR*, anterior root; *PR*, posterior root; *Gn*, ganglion of posterior root; *T*, trunk of spinal nerve.

branches are distributed. No effect is produced when the part still connected with the cord is galvanized or irritated. If now a posterior root be severed, and galvanism applied, the effects produced are directly opposite. Irritation of the distal part produces no effect, but when the part still connected with the cord is operated upon, extreme pain is produced, and is referred to the part of the body to which the distal end is distributed. The sensation of pain is received in the brain, and is referred to the part of the body which receives the terminal filaments of the sensory fibers.

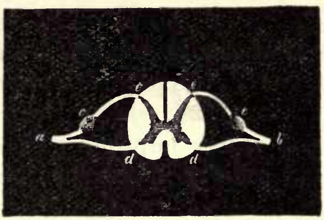

Fig. 89.—A transverse section of the spinal cord, showing the gray and white matter: *a–b*, spinal nerves of both sides; *e–e*, origin of the posterior roots; *d–d*, origin of anterior roots; *c–c*, ganglia of posterior roots.

The same effect is produced when the nerve which passes along the inner side of the elbow, familiarly known as the crazy-bone, is struck or injured. The pain is felt in the little finger, although the exciting

cause is applied to the nerve at the elbow. The sensation does not travel outward from the point of injury, but towards the brain, and the brain refers the pain to the part in which the sensory nerves find an ending. Analogous effects are produced by pressure along the course of a nerve. The part to which the nerve is distributed is said to be asleep, and can be pinched or pricked without causing pain. Peculiar effects are produced by this property of the nerves. If the end of the nerve in the stump of an amputated limb be irritated, the pain is referred to the hand or foot which was removed. From these facts it may be concluded that motor impulses pass only from within outward, and sensory impressions travel only from without inward.

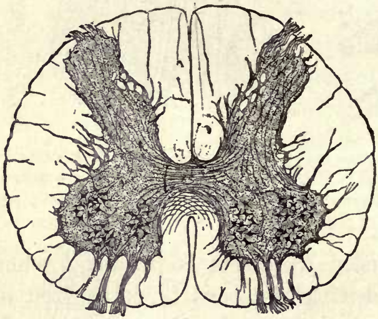

FIG. 90.—Transverse section of the spinal cord in man.

167. Transmission of Impulses through the Cord.—By experimenting upon the different columns and the gray matter of the cord, it has been shown that motor impulses pass through the fibers which form the posterior portion of the lateral columns. In the cervical region a large part of the columns is composed of these motor fibers.

These fibers gradually diminish as the roots are given off from the cord, and in the lumbar region form but a small part of the lateral columns. Sensory impulses probably pass to the brain through the gray matter, for,

if all the white substance of the cord be severed, only the gray matter remaining intact, sensory impressions still pass to the brain, although the power of motion is completely destroyed.

168. Decussation of Fibers.—The fibers of the cord which convey motor and sensory impressions do not pass directly to the brain. Those which unite with the right half of the cord pass to the opposite side before entering the brain, and *vice versa.* This is known as the *decussation* of the fibers, and the crossing of the motor tracts is plainly visible at the upper end of the cord. (Fig. 92.) The fibers cross in several distinct bundles, and are interlaced much as the fingers of the hands may be locked together. The sensory fibers also cross, but the point of decussation is by no means as distinct as that of the motor fibers. That both sets of fibers do cross is certain, for an injury to one-half of the brain disturbs the motion and sensation of the opposite half of the body. It seems probable that the sensory fibers cross to the opposite side at various points along the cord, for if one half of the cord be cut across at a point below the decussation of the motor fibers, loss of motion occurs on the same side, but loss of sensation takes place on the opposite side of the body. This would show that the sensory fibers had crossed to the opposite side below the point of section. If the spinal cord of a dog be split at its lower end, dividing the white and gray commissures, loss of sensation occurs in both hind legs, while the power of motion is retained. This fact would seem to show that the sensory fibers cross at their points of union with the cord, or very shortly afterward.

169. The Spinal Cord as a Nervous Center.—The spinal cord is not only a means of communication between the brain and the nerve-filaments which extend to all parts of the body, but in the gray matter are

nerve-centers in which impressions are received and impulses sent forth.

These centers are entirely independent of the brain, for, as has been seen, any interruption in the continuity of the cord results in a loss of voluntary motion and sensation below the point of section. The motions which may occur in the body as a result of stimuli applied

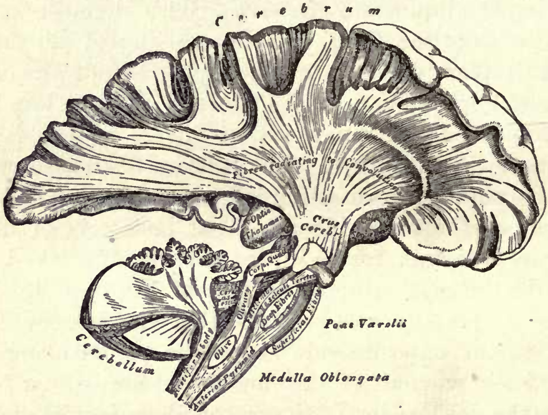

Fig. 91.—A diagram showing the medulla oblongata and its connection with the cerebrum and the cerebellum.

to the centers in the cord are never voluntary, and are known as reflex.

170. Reflex Action of the Cord.—If a frog be decapitated, and the foot be placed in an acid solution, it is immediately withdrawn. Irritation of the skin of the back may cause motion in both hind legs, so that the frog may leap to some distance as if to get away from the source of irritation. Like movements have been observed in human beings after injury to the spinal cord. Tickling the soles produces a drawing up of the feet, although the person is entirely unconscious that

the extremities have been touched, or that any movement has occurred.

That these motions are due to sensatory impressions conveyed to the cord may be shown by dividing the sensory roots at the point of union with the cord. If this be done in the frog, the leg on the side where the roots are severed remains quiet when the foot is immersed in an acidulated solution, but the opposite foot is quickly withdrawn.

That an impulse is sent along the motor nerves which pass to the muscles is evident, because, by dividing the motor roots which proceed from the anterior horns of the gray matter of the cord, motion is destroyed, as sensation was when the sensory roots were divided. Breaking up the gray matter of the cord also stops all reflex action. From these facts it may be seen that three things are necessary in the mechanism of reflex movements; viz.: a nerve to convey impressions, a nerve-center, and a nerve to transmit impulses. If the continuity of any one of these be interrupted, all action ceases.

171. Uses of Reflex Action.—In many of the reflexes there is a tendency towards a defence or preservation of the body. This is seen in the movements of the decapitated frog. The foot is drawn away from a source of irritation, or tries to push away any sharp instrument held against the skin. During sleep we unconsciously draw away from what irritates or annoys us. The feet are drawn up when tickled, and the face is turned if a light is suddenly brought into the room, yet we are quite unconscious of these actions. During waking hours the cord still acts. The hand is withdrawn from a hot iron before the brain has recognized the pain. In falling, the limbs are instinctively placed in the right position to break the fall. Walking, balancing, dancing, playing upon musical instruments,

etc., are all largely under the control of the spinal cord. The brain is called into action only at the beginning of the process, after which it may be occupied with other things, and the performance is controlled by the cord. Reflex movements are often beyond the control of the brain. If the tendon which unites the patella and the tibia be struck a quick, sharp blow, when the knee is bent, and the foot swings clear of the floor, the extremity is brought suddenly forward in spite of all efforts to prevent the movement. This is known as the patellar reflex, and any increase or diminution in its force is of importance in diagnosing diseases of the cord.

172. Diminished and Exaggerated Reflexes.—Diminished and exaggerated reflexes may be produced by administering drugs. Opium, chloroform, ether, etc., diminish the activity of the cord. Movements are less easily excited, and are performed with less accuracy and rapidity after these drugs have been taken. Strychnin, on the other hand, greatly increases the reflex. If a solution of this drug be injected under the skin of the decapitated frog, irritation, which before produced no movements, or only slight ones, now excites violent muscular action, and the frog may even make a succession of leaps, each leap after the first being caused by the shock of the fall from the preceding.

173. The Medulla Oblongata.—The medulla oblongata is that portion of the spinal cord within the cranial cavity. The fibers which form the posterior column of the cord separate and pass to either side, and the gray matter, which is considerably increased, is brought to view on the posterior surface. (Fig. 92.) The medulla is a continuation of the cord, and unites with the brain above. It possesses all the properties peculiar to the cord below this point, and is also the seat of other very important nerve-centers. In its gray

matter the cranial nerves, except the optic and olfactory, have their origin. These nerves find their way from the cranial cavity through various apertures in the bones of the skull and face, and pass to the eyes, ears, face, throat, lungs, head, diaphragm, and liver. They are called cranial nerves to distinguish them from the spinal nerves which have their origin in the cord external to the cranial cavity. (Figs. 92 and 93.)

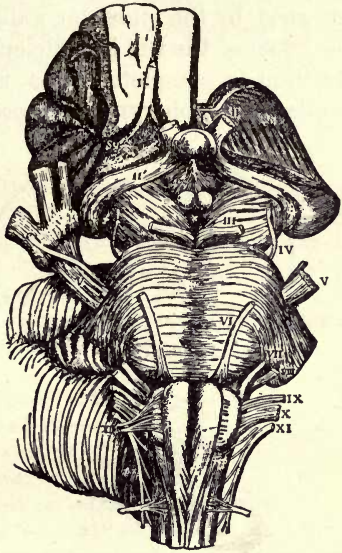

FIG. 92.—Showing the medulla oblongata, and the connection of the principal nerves with the brain. I–XII, the cranial nerves.

174. The Medulla as a Nervous Center.—The most important nerve-center found in the gray matter of the medulla is that of respiration. From this center, a small spot about 3 millimeters ($\frac{1}{8}$ of an inch) in diameter, all the muscles which aid in the process of respiration receive their stimulus. If the cranial cavity be emptied of its contents, the act of respiration is regularly performed, provided the medulla be uninjured. The sense of the want of air is conveyed to the medulla by the cranial nerves which supply the lungs, and an impulse is sent out through the motor nerves which pass to the muscles of respiration. It is simply a reflex action, and can be controlled for a time by the will, but the demand for air soon becomes imperative and the reflex action passes beyond the control of the will.

175. Deglutition.—Deglutition is also under the control of the medulla. The act of swallowing is voluntary until the substance reaches the pharynx, where it is grasped by the muscular walls of this tube, after which no effort of the will is sufficient to control the act. Deglutition is completed by a regular contraction of the walls of the pharynx and œsophagus, and is entirely a reflex action under the control of the medulla. The act is as perfectly performed during sleep, or unconsciousness due to some injury to the brain, as when we are perfectly conscious. Animals and birds whose brains have been removed, swallow food when it is placed far back in the throat; if left in the mouth or beak, no attempt is made to swallow, for the passing of any substance back to the pharynx is a voluntary action performed by the tongue and the muscles of the throat.

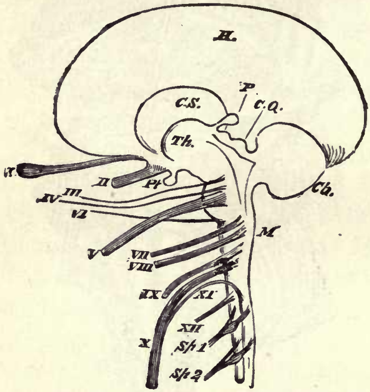

FIG. 93.—Diagram (schematic) showing the origin of the cranial nerves on the left side: *H*, cerebral hemisphere; *Cb*, cerebellum; *M*, medulla oblongata; I–XII, cranial nerves; *Sp.* 1–*Sp.* 2, spinal nerves; *CS*, corpus striatum; *Th*, optic thalamus; *CQ*, corpora quadrigemina.

The acts of *phonation* and *articulation* are also largely under the control of the medulla, for the cranial nerves send branches to the larynx, the tongue, and the lips. Experiments and experience teach that injury or disease of the medulla affects these acts.

The medulla oblongata is a most important part of the cerebro-spinal system, for its reflex centers control

the movements by which air and food are introduced into the body. Respiration is increased or diminished as the system demands more or less oxygen, the acceleration or diminution being a reflex act controlled by the center of respiration in the medulla.

QUESTIONS ON THE SPINAL CORD.

1. Describe the spinal cord.
2. What enlargements has the cord, and what are these enlargements called?
3. What is the arrangement of the white and gray matter in the cord?
4. Describe the nerve-trunks.
5. What conclusions have been reached through experiments made upon the roots of the nerve-trunks?
6. How are impulses transmitted through the cord to the brain?
7. What is meant by decussation of fibers?
8. Give the experiments which illustrate decussation.
9. Is the spinal cord a nerve-center?
10. What is meant by the reflex action of the cord?
11. What are the uses of reflex action?
12. How do different drugs affect reflex action?

QUESTIONS ON THE MEDULLA OBLONGATA.

1. What is the medulla oblongata?
2. What are the cranial nerves, and where do they have their origin?
3. What is the most important nerve-center found in the medulla?
4. What other acts are under the control of the medulla?
5. Why is the medulla an important organ?

CHAPTER XVIII.

THE BRAIN.

176. The Brain.—The brain is by far the largest collection of nervous tissue, and occupies the whole of the cranial cavity, except the small space taken up by the medulla.

It is composed of both gray and white matter, and is divided into two parts (Fig. 94), the cerebrum, or brain proper, and the cerebellum, or the little brain.

177. The Cerebrum.—The cerebrum is a large ovoid mass of white and gray matter occupying the whole of the upper part of the cavity of the skull. (Fig. 94.) It has the same general outline as the cranium, being separated from the inner table of the skull only by thin membranes, which surround it and line the skull. The cerebrum is divided by the great longitudinal fissure into halves, or hemispheres (Fig. 95), which are united near their under surfaces by a broad band of fibers which passes from one half to the other. These hemispheres also receive the several columns of the cord and bundles of fibers from the cerebellum. (Fig. 95.) The arrangement of the gray and white matter in the brain is the opposite of that in the cord; the various bundles of fibers which unite at the base of the brain form a large mass of white nervous tissue, which is almost entirely covered by a thin layer of gray matter; at various points this layer of gray matter dips down into the substance of the brain, forming deep fissures. (Fig. 94.) By this means the amount of gray matter is greatly increased,

and the surface of the brain thrown into numerous folds, or convolutions. These fissures and convolutions are somewhat variable in form, yet so constant in general outline that many of them have been named, and are distinctive points upon the brain-surface. (Fig. 96.) The most important are the fissure of Sylvius, and that of Rolando, and the parietal fissure. The convolutions

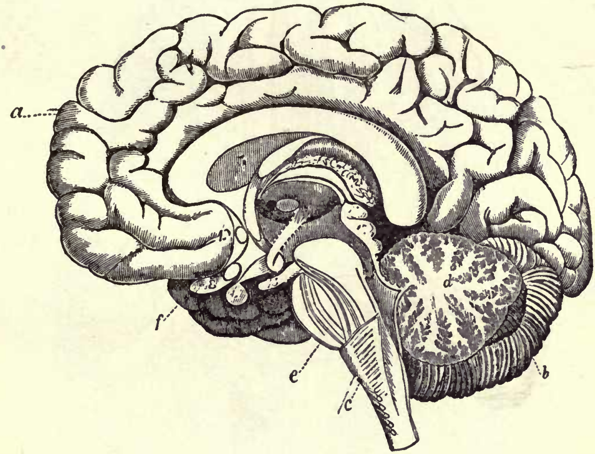

Fig. 94.—A median section of the brain, showing convolutions : *a*, cerebrum ; *b*, cerebellum ; *c*, medulla oblongata ; *d*, arbor vitæ; *e*, pons Varolii ; *f*, optic nerve.

which surround these fissures are always distinct, and are named according to their positions. (Fig. 96.)

178. Properties and Functions of the Cerebrum.—It has been shown in the description of the medulla as a nervous center (Sec. 174) that the cerebrum does not contain the center, or centers, which are the primary seat of life, for an animal may live for some time without a cerebrum. The various functions are performed with some degree of regularity without the direct consciousness of the creature; circulation is kept up,

respiration goes on, food is swallowed and digested, and the digested food is absorbed and assimilated; these functions are performed although the creature be in a state of apathy. When the creature is disturbed, it rouses for a moment, and tries to move away from the

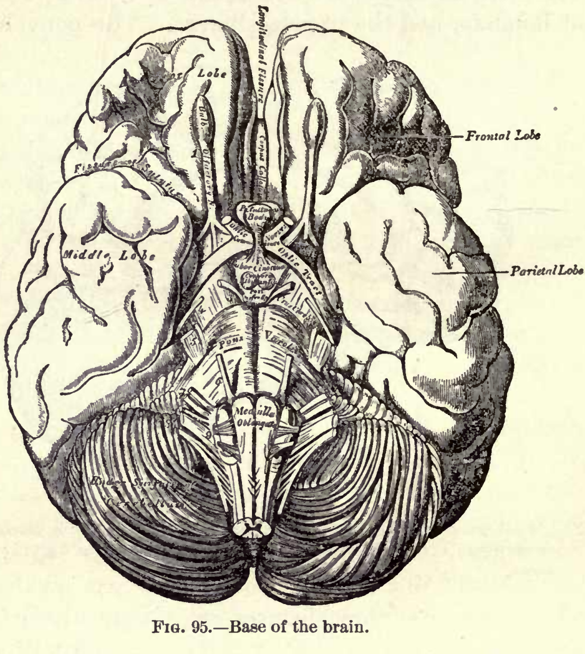

FIG. 95.—Base of the brain.

source of irritation; when left to itself, it quickly returns to a semi-conscious condition. The sense of fear is lost. The discharge of a pistol, or any loud noise, may cause the animal to open its eyes, but no effort is made to move away. The creature fails to understand the significance of what is occurring; its instinct is gone. Life exists without voluntary power to control the actions or to direct the movements.

In the cerebrum reside those faculties which guide and control the physical, mental, and moral actions of life.

179. Memory.—Memory, the simplest, yet perhaps the most important, of all the mental faculties, has its seat in the cerebrum. Without memory there could be little or no mental activity, for we depend largely upon this faculty in the performance of the simplest acts.

Memory is the faculty which permits of the accom-

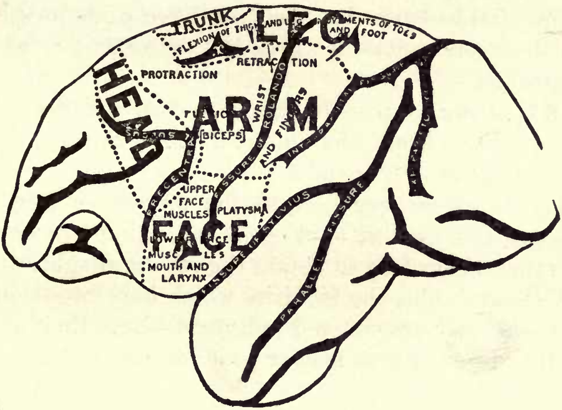

FIG. 96.—Showing motor areas on the outer and the median surface of the brain.

plishment of any act of mind or will that is associated with things which are past, as speaking, reading, writing.

If the memory of a child be entirely defective, the mind will never develop. When persons lose their memory they become simple and childish ; the experience of a lifetime slips from them, and with it the ability to reason and the power to judge. Memory is the faculty preëminent which permits of mental advancement.

180. Reason.—Reason, which is the faculty of appreciating nervous impressions, and referring them to their external causes, is also inherent in the cerebrum.

The idiot may perceive all that passes before the eye, and nervous impressions may be carried to the brain with accuracy, yet the power to understand the relations between cause and effect is partially or wholly wanting.

People who are weak-minded, or have partially lost their memory, reason in a defective manner. They look for results that are unlikely to follow certain causes.

The imaginings of the insane are the result of defective reasoning.

They fail to appreciate the true force of impressions, and their conclusions are greatly exaggerated or wholly impossible.

181. Judgment.—Judgment is closely allied to reason, and is the faculty by which certain means are chosen to accomplish certain ends.

Reason enters largely into the process of selecting those means, and without good reasoning powers the judgment often fails to obtain the results sought.

Without doubt, the faculties which have been considered—memory, reason, and judgment—have their seat in the thin layer of gray matter which forms the outer surface of the brain.

Generally speaking, the intellectual power is proportionate to the amount of gray matter present.

The brain in which the mental faculties are highly developed is generally large, the fissures deep, and the convolutions well marked. In a child these marks of high intellectual power are not found, but as the memory is cultivated and reason and judgment assert themselves, the brain increases in size, the gray matter extends deeper into the brain-substance, and the convolutions become more marked.

The brain, like the muscles, may be developed by exercise.

The various mental faculties will gain strength and

activity under judicious training, and mental gymnastics are found as stimulating to the brain as physical training is to the muscles. On the other hand, as in the case of the muscles, exercise to the point of exhaustion is always injudicious.

"Fatigue in every shape is fatal to memory. The impressions received under such conditions are not fixed, and the reproduction of them is very laborious and often impossible."—Ribot's *Diseases of Memory*.

"Just as muscular exercise causes an increased growth of muscular fiber, so regulated mental exercise must develop and strengthen the tissue of the brain."—Drs. M'Kendrick and Snodgrass.

"Those who labor much with their brains need a more generous diet than any other class of people. Meat and fruits should be eaten in abundance. The nation proverbially known as 'beef-eaters' has furnished the world the greatest literature of all time."—Halleck.

182. Other Centers.—Besides being the seat of the intellectual powers the cerebrum contains the centers of voluntary motion, sensation, speech, smell, taste, hearing, pain and temperature, the emotions, and the passions.

These centers have been more or less distinctly located, and when one or more of these faculties are affected or destroyed by disease, some idea may be had as to the location of the malady.

The areas which control motion have been quite correctly mapped out, and any irritation of the gray matter contained in these areas produces convulsive movements in the muscles, or groups of muscles (Fig. 96), which receive the nerve-filaments from this part of the brain.

183. The Will.—The cerebrum is also the seat of

the will. Impulses arise in the brain, and we will to do or not to do certain things.

In fact, the will controls all our voluntary acts.

It is presided over in great measure by the faculties—memory, reason, and judgment—but when once a question is decided in the mind, the will directs our actions.

184. The Emotions.—The emotions are awakened by external influences which produce an impression in the brain.

We are joyous or sad according to our surroundings.

Our grief is awakened at the affliction of friends, and pity is felt at the sight of misery and want.

185. The Passions.—The passions are also aroused by what occurs around us, and the will is often taxed to its utmost to control our actions while under their influence.

The mind of man is so constituted that bodily ailments affect the clear working of the faculties. During indisposition, mental, like physical, work can be accomplished only by a great effort of will.

The cerebrum, as a whole, is a most complex organ.

In the nerve-centers of the hemispheres reside those peculiar traits, inherited or acquired, which give to each person character and individuality.

Some of these traits may be overcome by the right kind of training. We are largely creatures of habit, and a habit usually can be broken by constant thought and exercise of the will.

We gain in will-power, as in mental and physical power, by exercise.

"From the broadest point of view memory is habit. In memory the nerve-cells are again acting in a way in which they have acted before."—Reuben Post Halleck.

"The greatest difficulty with the nervous system is that it so often fails to have the aid of discipline and of

will-power. As there is tonic to the whole body in air, water, and sunshine, so there is tonic to the nervous system in willing obedience to that which is right in discipline and self-control.

"We fortify the nervous system in studying how to control action, motion, sensation, volition, and all that appertains to that wonderful border-land between the voluntary and involuntary, of which brain and nerves are the communicating telephones."—Ezra M. Hunt, A.M., M.D., President American Health Association.

186. Properties and Functions of the Cerebellum.—The cerebellum, or little brain, is situated in the posterior and lower part of the cranial cavity, beneath the cerebrum and back of the medulla. (Fig. 95.)

Like the cerebrum, it is divided into halves by a deep fissure, and the white and gray matter have the same general arrangement as in the cerebral hemispheres.

The convolutions have a laminated appearance, and are smaller and more compact than in the cerebrum.

The cut surface shows a peculiar branched or foliated condition of the white and gray matter, known as the *arbor vitæ*, or tree of life. (Fig. 94.)

The cerebellum receives bundles of nerve-fibers from the posterior and lateral columns of the spinal cord; fibers pass from the cerebellum upward to the cerebrum, and the two halves are united by a broad band of white fibers which passes across the anterior surface of the medulla, and is known as the *pons Varolii*. (Fig. 95.)

187. Physiological Properties of the Cerebellum.—The cerebellum, like the cerebrum, may be entirely removed without destroying life.

The mental disturbances which accompany destruction of the cerebral hemispheres do not occur when the cerebellum is removed from a creature, but there is inability to direct and control voluntary movements.

There is no loss of muscular power, but there is uncertainty in the movements of the limbs. The creature may be unable to walk or to fly, or, at best, these acts are performed in a very awkward manner.

When approached hastily there is every manifestation of fright, and violent efforts are made to escape, but these efforts are only exaggerated, irregular movements of the limbs or wings.

There is staggering or fluttering and falling because of inability to make coördinate movements. The various groups of muscles which move the legs or wings do not act in harmony, and the movements are disordered and irregular.

The function of the cerebellum is, therefore, to control and harmonize the muscular movements so that motion may be steady, exact, and directed toward the accomplishment of some particular object.

QUESTIONS ON THE BRAIN.

1. What is the brain? Of what is it composed, and how is it divided?
2. Describe the cerebrum.
3. How does an animal deprived of its cerebrum behave? What conclusions are deduced from this behavior?
4. What faculties reside in the cerebrum?
5. What is meant by memory? reason? judgment?
6. What other centers does the cerebrum contain?
7. What is meant by the will?
8. What is the effect of physical maladies upon the brain?
9. Describe the cerebellum.
10. Define the *arbor vitæ* and *pons Varolii.*
11. What is the behavior of a creature deprived of the cerebellum?
12. What conclusions are drawn?

SUGGESTIONS FOR EXPERIMENTS ON THE NERVOUS SYSTEM.

In the experiments hitherto given or suggested it has generally been possible to secure from a good market, or from a butcher, such parts of animals as would serve to illustrate admirably many of the characteristics of structure and the uses of the parts under observation.

The physical structure of the various parts of the nervous system, the brain, spinal cord, etc., as well as their inaccessibility—they being encased within bony cavities—render it a matter of some difficulty to secure such specimens as will give clear ideas of their natural appearance and structure.

These difficulties should not be allowed, however, to prevent a careful examination of these very important organs.

The authors do not believe it wise or humane to encourage pupils to kill frogs, cats, dogs, or animals of any sort, even to furnish material for experiments.

If it be deemed necessary to secure specimens in this way, they should be prepared by the teacher. The teacher should never expect or encourage a pupil to do what she herself has not the heart to do.

It will be found best to resort again to the marketman, who can furnish the skull, with a part or all of the spine attached, of some of the smallest animals usually found in a market—such as a squirrel, rabbit, or even a small lamb or calf.

In removing the brain from the cavity of the skull, care should be taken to leave portions of the cranial nerves; like care should be exercised to preserve stumps of the spinal nerves while removing the cord from the spine.

The conspicuous features of these principal organs of the nervous system may now be observed; note the membranes lining the skull and surrounding the brain, the softness of the brain in its normal state, its size, form, color, etc.

The weight of the animal from which the brain is to be removed may be ascertained, and the weight of the brain and that of the animal compared.

Examine the cerebrum: compare its size with that of the cerebellum; note its position in relation to other parts; consider how thoroughly it is protected by the surrounding walls of bone; observe its convolutions, its division into right and left hemispheres, etc.

Examine the cerebellum: note its connection with the medulla oblongata by means of nervous tissue passing into it from the medulla on each side ; also by the large "bridge" of tissue known as the pons Varolii.

Examine the pons Varolii.

The medulla oblongata should be carefully observed ; note its position, the admirable way in which it is protected, its attachments to other parts, etc., etc.

The spinal cord should next receive attention.

Note its diameter, its length (in a man of average height it is about 45 centimeters [18 inches] long, terminating at about the second lumbar vertebra, and about half an inch in diameter), its fissures, stumps of nerves, surrounding tissues, etc.

CHAPTER XIX.

EFFECTS OF DRUGS ON THE NERVOUS SYSTEM—ALCOHOL, OPIUM, AND TOBACCO.

188. Effects of Narcotics.—"No one cause of injury to the nerves and brain known to our modern life can at all compare with that attributable to alcohol and other narcotics. This injury is greatly enhanced not only by popular misapprehension as to the facts, but by a false confidence in alcohol, and ignorance of the danger which inheres in beginning its use."—*School Physiology Journal.*

The effects of narcotics are due to a direct action of their active principles on the cerebro-spinal centers.

They are absorbed and carried unchanged to the brain and spinal cord, and here produce their deleterious effects.

189. Alcohol.—Alcohol has been found in the fluids in and around the brain, and has been distilled from the brain-substance itself.

In habitual drunkards, the alcohol which is repeatedly carried to the brain produces structural changes in the gray and white matter. The brain, as a whole, becomes shrunken, and its fluids are proportionally increased.

The cells of the gray matter contain fatty granules, and the axis-cylinders undergo partial degeneration.

These changes are accompanied by impaired intellectual power, loss of will, and of moral sensibility.

The whole being is degraded, not only intellectually and morally, but physically.

There are muscular tremblings, shambling gait, and the characteristic maudlin speech.

Laws have been enacted which nullify certain legal transactions made when a person is under the influence of alcohol.

Drunkenness does not excuse a breach of the peace, theft, or murder, or lessen moral responsibility.

In fact, drunkenness is a crime which, in many places, is punishable by fines and imprisonment; but acts which pertain to the transfer of property, such as the signing of deeds and mortgages, will not stand in law if the person, when signing, was under the influence of liquor.

Many people believe that confirmed drunkards should be confined in asylums and treated medically, as insane persons are treated. There is a tendency to look upon such persons as diseased individuals incapable of breaking the habit which controls them.

However this may be, the will-power is certainly weakened or lost, appetite has become master, and to satisfy this tyrant reason and judgment are violated, and manhood degraded.

"All indications point to the conclusion that it is the nervous tissue which is especially exposed to the cumulative action of the alcoholic poison. The alcohol sets up a chemical action in the nervous tissue, which at first inaugurates only imperceptible changes, but once inaugurated, the poison goes on until the tissue passes into a permanently diseased condition."—A. Strumpell, M.D., Berlin.

"The children of drinking parents do not inherit a healthy nervous system. It has been shown that a large percentage—*i.e.*, about half—of the inmates of institu-

tions for feeble-minded children, for epileptics, and for deaf-mutes, are the children of drinking parents."—Dr. Adolph Frick, Zürich.

"The habitual use of alcoholic liquors, to an extent short of what is necessary to produce drunkenness, injures the body and diminishes the mental power to an extent which, I think, few people are aware of."—Sir Henry Thomson, M.D., Professor of Surgery and Pathology, Royal College of Surgeons, London.

"Helmholtz has said, in describing his methods of work, that slight indulgence in alcoholic drinks dispelled instantly his best ideas. Professor Gaule once told the writer that, as an experiment during the strain of his 'Staatsexamen,' he suddenly stopped his wine and beer, and was surprised to find how much better he could work. An eminent professor in Leipsic once said that the German students could do 'twice the amount of work' if they would let their beer alone. Dr. August Smith has found that moderate non-intoxicant doses of alcohol (forty to eighty cubic centimeters daily) lowered psychic ability to memorize as much as seventy per cent."—C. F. Hodge, Ph.D., Assistant Professor of Physiology, Clark University. *Experiments on Physiology of Alcohol, made under the auspices of the Committee of Fifty.*

"Alcohol is, in the first place, a brain-poison. What do heart or liver-diseases, what does death even, signify in comparison with an unbalanced mind? Mental disorders are far worse than death, for they destroy the germ of human personality, the humanity in man. The poisoning of the brain by alcohol is all pervasive. We need not descend to the drunkard. In looking at the moderate drinker we see that his sensibilities are less fine, he cares less for the strict truth, he is more negligent of the proprieties, less active mentally, etc."—Dr.

August Forel, Professor of Psychiatry at University Zürich, Director Insane Asylum, Burgholzli.

"The flushing of the face (produced by alcohol) is caused by the paralysis of the cervical branch of the sympathetic nerve. This symptom usually occurs some time before the conspicuous manifestation of the ordinary signs of intoxication which result in paralysis of the cerebrum; we may search in vain among the phenomena of intoxication for any genuine evidence of that heightened mental activity which is said to be followed by depressive recoil. There is no recoil, there is no stimulation. There is nothing but paralytic disorder from the moment narcosis begins."—Professor John Fiske, Cambridge, Mass.

190. Opium.—Opium in its various forms is almost as destructive to the faculties as alcohol.

It is less frequently used in this country, and consequently its effects are less obvious, yet the opium-habit when formed is exceedingly hard to overcome.

It impairs the mental traits which make human nature gentle, kind and lovable, deadens the sensibilities, weakens the will, and injures the memory.

It destroys the sense of shame and delicacy and brings out the grosser elements of character. It finally results in failure of the nervous system and partial paralysis.

It is often prescribed by physicians for the relief of pain, and, if continued for some time, its use becomes habitual.

The growth of the habit is rapid and insidious, and almost before the person is aware of it the appetite is formed, the system craves the drug, and all sorts of deceptions are resorted to in order to obtain it.

It should not be used as a household remedy without the most explicit directions from a physician.

Most medical men are alive to the danger of prescribing it, and do so with extreme caution.

Laudanum, morphia, and paregoric are the several forms in which it is administered.

Very many patent medicines, "soothing syrups," "tonics," and "bitters," contain some form of opium, or depend for their effects on alcohol.

Children are very sensitive to all preparations of opium.

Dr. H. Newell Martin says: "Opiates should never be administered to children, except by order of a physician. Many an infant has been poisoned by a few drops of paregoric, or some soothing syrup given by parent or nurse."

Women, quite as frequently as men, are the victims of the opium-habit.

Chloral is another drug very similar in its effects to opium. The chloral-habit is very easily formed, and is broken only with intense mental and physical suffering.

191. Tobacco.—Tobacco is used so generally that its action as a drug is nearly lost sight of.

The active principle, nicotine, is a violent poison.

Very little of this substance is taken into the system when tobacco is chewed or smoked.

The fumes of tobacco contain no nicotine, for the alkaloid, as it is called, is destroyed by the heat of the burning leaves.

Tobacco contains an oil which is poisonous. It is this oil which causes the sickness which usually accompanies its first use. The nerve-center which controls the heart is sometimes affected by tobacco. There is irregular action of this organ, together with a heaving or lifting sensation in the chest, which is very distressing.

It has also an effect upon the eyes if it be used to excess.

Tobacco is most harmful to a growing body. It is detrimental to the whole system, hindering the development of both muscular and nervous tissue.

So harmful is the action of this substance upon the undeveloped system that, in many States, laws have been passed forbidding its sale to minors.

The most pernicious form in which tobacco is used is the cigarette. The smoke is drawn into the lungs by the expert smoker, and a percentage of this smoke, and other poisonous substances which the cigarette may contain, are taken up by the blood and carried to all parts of the body.

The use of tobacco has been forbidden in the military and naval academies of the country, as its use seriously affected the health and endurance of the cadets.

Athletes are not allowed to use tobacco, except in very small quantities, while in training.

The muscular tremor of the tobacco-consumer is often very apparent; the fingers tremble, and the whole body is somewhat unsteady, so that acts requiring "steady nerves," such as shooting or the doing of certain kinds of delicate work, are but poorly performed.

"There is a connection, often marked, in the use of the different narcotics. The alcohol habit tends to produce the opium habit, and the reverse; one may be substituted for the other, and the two are often indulged together. The same principle, to a greater or less extent, applies to the widespread tobacco habit, and to the less prevalent chloroform, chloral, and hasheesh habits. The indulgence in any one begets a tendency to indulge in others. The habitual use of any of them produces a constitutional narcotic state, different from the normal."—Dr. A. B. Palmer, Dean of Medical Department of the University of Michigan.

"The future health and usefulness of the lads in our

naval schools require the absolute interdiction of tobacco in any form."—Medical Director, U. S. Navy.

"Tobacco creates a thirst, to remove which alcoholic stimulants are often resorted to."—Dr. Copland, F. R. S.

"The German Government has ordered the police to forbid boys under sixteen years of age smoking in the streets, because of its evil effects on mind and body."—Charles H. Stowell, M.D.

"In France the difference between the students in the polytechnic schools who smoked cigarettes and those who did not, in scholarship, as shown by their respective class standings, was so great that the government prohibited absolutely the use of tobacco in all government schools."—Dr. William A. Hammond.

The Committee on Color Vision of the British Royal Society reported: "After the most arduous investigation, the committee find that though alcohol rarely, if ever, causes this defect in vision, it results very frequently from the smoking of strong tobacco, the most prevalent form being the inability to distinguish red from green; these colors usually appearing white."

CHAPTER XX.

THE SYMPATHETIC SYSTEM.

192. The Sympathetic System.—The sympathetic system consists of a double chain of ganglionic nerve-centers, extending from the brain downward through the neck, chest, and abdominal cavity.

These ganglia are composed of gray cells, similar to those found in the cerebro-spinal system, and are bound together by bundles of nerve-fibers, which pass downward upon each side of the spinal column and unite in front of the coccyx in a single ganglion known as the *ganglion impar.* (Fig. 97.)

These ganglia of the sympathetic system communicate with the spinal cord by means of branches which are given off from the spinal nerves soon after their exit from the spinal canal, and probably the system receives its innervation through these fibers; that is, the various phenomena which take place in the organs and parts of the body supplied by the sympathetic system have their origin in the cerebro-spinal system.

From this chain of nerve-centers numerous branches are given off, which are distributed to the various organs of the body. These branches contain both motor and sensory fibers, but they act with much less rapidity than the nerves of the cerebro-spinal system. If a stimulus be applied to one of the ganglia, some time may elapse before motion occurs in the organs to which the motor fibers are distributed.

Sensory impressions also travel slowly, and several

seconds are required for an impression to reach a ganglion.

There is a strong tendency in the branches of this system to arrange themselves into networks, or plexuses, about the special organs to which they are distributed.

These plexuses are named according to their various situations, and the different organs which they supply.

The blood-vessels also receive their nerves from the sympathetic system.

Nervous branches follow the vessels throughout their ramifications, and give off filaments, which supply the involuntary muscular fibers of the middle coat.

These nerves give tone to the blood-vessels, and regulate the supply of blood to the various organs of the body.

It is through the sympathetic system that most of the involuntary muscular fibers of the body are innervated.

Blushing is the one action of the sympathetic system of which we are conscious.

The movements of the stomach and intestines during digestion and absorption are regulated through the fibers of this system, and the blood-supply of these organs is also controlled by them.

Fig. 97.—Ganglia and nerves of the sympathetic system.

The whole system presides over the nutritive functions of the body.

QUESTIONS ON THE SYMPATHETIC SYSTEM.

1. Of what does the sympathetic system consist?
2. What is the *ganglion impar?*
3. How does the sympathetic system receive its innervation ?
4. With how great rapidity do the sympathetic nerves act ?
5. What tendency have the branches of this system ?
6. How do the blood-vessels receive their nerves, and of what use are these nerves ?
7. What muscular fibers are innervated through this system ?
8. Of what act of the sympathetic system are we conscious ?
9. Over what does this system preside ?

CHAPTER XXI.

THE SENSES—TOUCH, TASTE, SMELL.

193. The Senses.—All animals are endowed with one or more senses, through which external objects are perceived and some knowledge of the surrounding world is obtained.

The amœba, the lowest form of animal life, draws itself away from certain things which irritate it, and although it possesses no organized nervous system, it is still capable of receiving impressions.

The higher animals are endowed with five senses, and these are the channels through which all information, relative to things external to the body, is obtained.

These five senses are, (1) the sense of touch, or general sensibility, (2) the sense of smell, (3) the sense of taste, (4) the sense of sight, and (5) the sense of hearing.

194. General Sensibility.—General sensibility exists over the entire surface of the body, and by means of it we recognize the various properties—as consistency, mass, temperature, surface, etc.—of objects about us.

Although these impressions are entirely different in character, and the stimuli which produce them are also quite different, so far as is known they are conveyed by the same nerves.

195. The Sense of Touch.—The sense of touch is perhaps the simplest of the special senses.

Through it we learn the properties of objects about us; their hardness, softness, shape, size, etc.

It is doubtful if the difference between a ball and a

disk could be told, unless we first learned it through the sense of touch.

The degree of sensibility varies in different parts of the body. The tip of the tongue is the most sensitive, the ends of the fingers next, while the skin of the middle of the back is the least sensitive. This statement may be verified by applying to the various parts of the body the points of a pair of compasses. Over the more sensitive parts the two points can be felt when very near each other; over the back the points must be as much as 50 millimeters (2 inches) apart before two distinct impressions can be felt.

The hand is the most perfect organ of touch, because of its construction. The fingers are flexible, and by means of them an object is readily grasped and held.

In animals, the long bristles on the nose and lips act as "feelers." Each hair is connected with a sensitive papilla, and, although the hair itself is not sensitive, the least touch at the end of the hair creates a sensation in the papilla.

In an elephant the end of the trunk is the principal organ of touch.

The degree of sensibility of any portion of the body is in proportion to the number of sensory fibers ending in the part.

196. The Sensation of Pain.—The sensation of pain is closely allied to the sense of touch.

So far as is known, the same nerves carry the two sensations to the brain, yet the two impressions differ in character.

If pressure be applied to any part of the body until the sense of touch is lost, the sensation of pain may remain.

Tactile sensibility may also remain after the ability to feel pain is lost.

The patient often speaks of having felt the operation, during ether or chloroform inhalation, without experiencing any pain.

The application of heat or cold beyond a certain point produces the sensation of pain, and the feeling is the same whether caused by heat sufficient to burn, or by cold sufficient to freeze.

The sensation of pain gives no idea of the shape or character of the exciting cause.

When we receive an injury we do not recognize the cause until we look upon or feel of the object which produces it.

We learn from experience what things give pain, and studiously avoid them. The old saying, "A burnt child dreads the fire," finds its full illustration in our daily lives.

Without this constant reminder of what is harmful we should often inflict injuries upon ourselves.

Pain is often a symptom of disease. Indeed, the word "disease" was formerly used to denote the presence of pain, or the absence of ease. Pain is the warning which nature gives when the system has imposed upon it the work caused by our vicious habits, and the intemperate use of those things which, when rightly used, are useful and wholesome.

197. The Sensation of Temperature.—By the sensation of temperature we distinguish between the various degrees of heat and cold.

Generally speaking, the parts which are most sensitive to tactile impressions are most sensitive to temperature.

The scalp does not feel heat and cold as do the face and hands, nor is the skin of the back so sensitive to changes of temperature as the skin of the breast and arms.

Sensibility to temperature, like sensibility to pain,

may remain after the power to receive tactile impressions is gone, or it may be lost while tactile sensibility remains unimpaired.

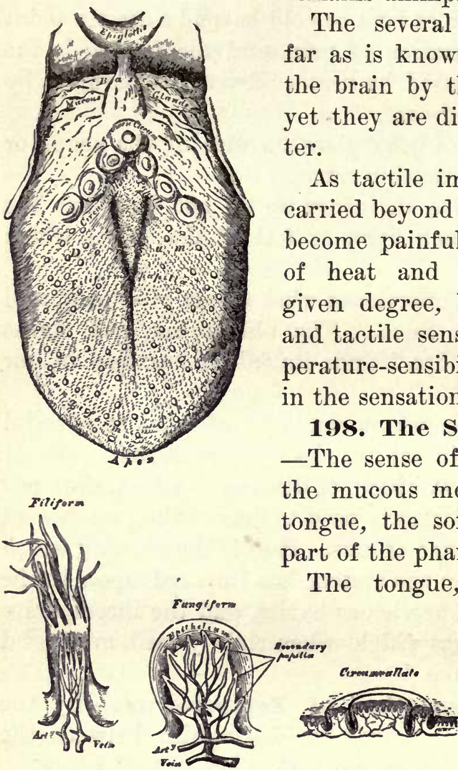

FIG. 98.—Upper surface of the tongue, and the different kinds of papillæ.

The several impressions, so far as is known, are carried to the brain by the same nerves, yet they are distinct in character.

As tactile impressions, when carried beyond a certain point, become painful, so impressions of heat and cold, beyond a given degree, become painful, and tactile sensibility and temperature-sensibility become lost in the sensation of pain.

198. The Sense of Taste.—The sense of taste resides in the mucous membranes of the tongue, the soft palate, and a part of the pharynx.

The tongue, in which the sense of taste is most perfectly developed, is shaped somewhat like a leaf. Its base is attached to the lower jaw and to the hyoid bone. (Fig. 98.)

It is composed of muscular fibers which run in various directions and give to the organ great mobility. It can be protruded, drawn backward, and moved to all parts of the mouth.

The upper surface, or dorsum, of the tongue is covered with papillæ, in which the nerves of taste find an ending. (Fig. 98.)

The portions of the mucous membrane of the mouth and throat which are the seat of the sense of taste have been determined by touching the tongue and throat with a bit of sponge, or some small object, holding a sweet or bitter solution.

In this way it is shown that the tip and edges of the tongue are the most sensitive, especially to sweet substances, while the back part of the tongue, the palate, and part of the pharynx, are more susceptible to sour and bitter tastes.

The sense of touch is most delicate in the tip of the tongue, and often gives an impression of taste when, in reality, the substances in question possess little or no savor. This is true of oily or mucilaginous substances, starch, flour, etc., which, in reality, have very little taste, though they produce a feeling in the mouth which is often confounded with the sense of taste.

The sense of taste is also closely associated with the sense of smell.

The aromatic properties or flavors of various articles of diet, such as tea, coffee, spices, etc., produce their agreeable impressions as much through the sense of smell as by their savory properties.

During a cold in the head these articles are comparatively insipid. This is due to the blunted condition of the sense of smell.

Generally speaking, articles which are agreeable to the taste are wholesome.

The sense of taste, therefore, is a valuable guide in selecting such articles of diet as the system craves, and such as will keep the body strong and healthy.

A taste for certain articles may be acquired, or an

article which has been most palatable may become exceedingly disagreeable.

During childhood and youth a plain, wholesome diet satisfies, and articles having strong, peculiar flavors are disagreeable.

Tastes for onions, olives, olive oil, tomatoes, celery, and many of the spices and peppers are usually acquired, and some persistence is necessary before these articles can be taken with relish.

As we grow older the sense of taste becomes blunted to some extent, the appetite becomes capricious, and articles which have stimulating odors and strong flavors are taken with relish.

To excite the sense of taste a substance must come into direct contact with the nerve-endings of the mucous membrane of the mouth and throat, and it must be in solution before it can affect these nerves.

When the mouth is dry, food has very little taste, but when the secretions are copious, the food becomes a soft, pulpy mass, which is passed from side to side of the mouth and pressed against the tongue ; its savory qualities pass quickly into the mucous membrane to the nerve-endings, and the sense of taste is awakened.

The sensations of taste, when once roused, may continue for some time. Very sweet, or bitter, substances leave an impression which may last for some minutes, and sometimes for hours. This fact may be taken advantage of in the administration of disagreeable medicines. If some substance with a high flavor be held in the mouth, the impression is so lasting that the medicine may be quickly swallowed, and will leave but little taste.

199. The Sense of Smell.—The sense of smell is seated in the mucous membrane which lines the nasal passages.

This membrane is known as the "Schneiderian" membrane, and is supplied with common sensory nerves as well as with olfactory nerves. (Fig. 99.)

200. The Nasal Cavity.—The nasal cavity extends from the nostrils in front to the upper part of the pharynx behind, and is divided by the nasal septum into two cavities, or passages, through which air is taken into the lungs.

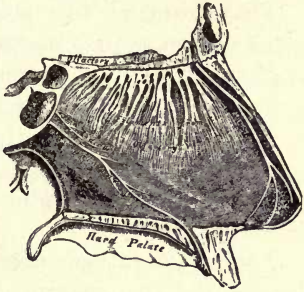

FIG. 99.—Showing the olfactory nerves of septum of the nose.

The inner walls of these passages are smooth and regular, but to the outer walls are attached the turbinal bones—superior, middle, and inferior. (Fig. 100.)

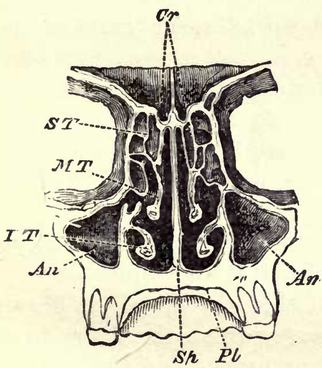

FIG. 100.—A vertical section of the nasal passages: *Sp*, septum; *Pl*, palate; *ST*, *MT*, *IT*, the superior, middle, and inferior turbinal bones; *Cr*, cribriform plate; *An*, chamber of the upper jaw-bone.

They are in the form of a scroll, or half-roll, and greatly increase the surface of the nasal passages.

The inner and outer walls of these passages are covered by the Schneiderian membrane, and about the nostrils there are numerous short, coarse hairs, which catch dust and small particles of foreign matter which otherwise might find their way into the lungs.

201. The Olfactory Nerves.—The olfactory nerves

arise from the under surface of the brain and pass forward to the upper surface of the ethmoid bone, just above the nasal passages. (Fig. 95.)

They form, at this point, small club-shaped expansions known as the olfactory bulbs ; and from the under surface of each numerous branches are given off to supply the nasal passages.

These branches find their way into the nasal cavity through small openings in the ethmoid bone, and form a network, or plexus, which covers the upper part of the nasal passages.

The plexus extends over the inner and outer walls as low as the free margin of the middle turbinal bone ; below this point the mucous membrane is supplied with common sensory nerves only.

202. Conditions of Sense of Smell.—The sense of smell is excited when a gas or vapor having odoriferous properties comes in contact with the filaments of the olfactory nerves.

During ordinary respiration faint odors may escape detection, for the current of air moving through the nasal passages may not rise so high as the middle turbinal bones, and so may not come in contact with the olfactory branches.

When faint odors are perceived, almost involuntarily a full inspiration is taken, or the air is drawn into the nose in short jerks or sniffs. In this way the air is drawn upward into the nasal passages, where the fibers from the olfactory bulbs are most numerous and the sense of smell is keenest.

This is best illustrated by the lower animals, in which the sense of smell is extremely delicate.

In order to excite the sense of smell the odoriferous substances must come in contact with the olfactory nerves.

It is probable that the substance containing the odor is dissolved in the secretions of the nose and carried to the nerve-endings, which are very near the surface of the Schneiderian membrane.

It is difficult to describe most odors. Some substances smell sweet, others sour, and in these instances smell and taste agree, but there is no smell which corresponds to alkaline or bitter tastes.

203. The Uses of the Sense of Smell.—The sense of smell, like that of taste, is helpful in selecting our food.

Generally speaking, the articles which have pleasant odors, and excite the appetite, are healthful and agreeable.

The principal uses of this sense, however, are to give pleasure, and to detect odors and gases which are injurious to the health when taken into the system.

Pungent, acrid, or powerful odors of any kind should not be breathed for any length of time, for they often emanate from poisonous substances and contain more or less poisonous matter.

QUESTIONS ON THE SENSES.

TOUCH, TASTE, AND SMELL.

1. What is the use of the senses ?
2. With how many and what senses are the higher animals endowed ?
3. What is meant by general sensibility ?
4. What do we learn through the sense of touch ?
5. What part of the body is most sensitive, and what least sensitive ?
6. What can you say of the organ of touch in different animals ?
7. What other sensations are closely allied to that of touch ?
8. What is pain ?
9. What parts of the body are most sensitive to temperature?
10. Where does the sense of taste reside ?

11. Describe the tongue.
12. What parts of the mouth are most sensitive to sweet, and what parts to sour, substances ?
13. What sense is sometimes confounded with taste ?
14. Of what value is taste ?
15. How is this sense excited ?
16. What suggestion is made in regard to unpleasant medicines ?
17. Where is the sense of smell located ?
18. Describe the nasal cavity.
19. What are the olfactory bulbs ?
20. What other than olfactory nerves are found in the nasal cavity ?
21. How is the sense of smell excited ?
22. What are the uses of this sense ?

CHAPTER XXII.

THE SENSE OF SIGHT.

204. The Eye.—Of all the senses, that of sight is the most remarkable; and the organ of sight, the eye, is the most complicated organ of the sensory apparatus.

The eye is a nearly spherical body composed of coats, or layers, which enclose the refracting media.

It is situated in the socket, or orbit, which is formed by the bones of the cranium and face.

The orbit furnishes attachment for the ocular muscles, and gives protection to this delicate organ.

The eye is connected with the brain by the optic nerve. (Fig. 95.)

205. The Sclerotic Coat.—The sclerotic coat, or outer layer, is a dense, white membrane composed of strong fibers of connective tissue. It is opaque, and is known as the "white of the eye." It furnishes attachment for the ocular muscles. (Fig. 101.)

206. Cornea.—The cornea forms the front of the eye, and takes its name from its hard, horny appearance. (Fig. 101.)

It is continuous with the sclerotic coat, but is transparent, and is the most prominent part of the eyeball. It is as though a circular aperture had been made in the sclerotic, and a segment from a smaller, transparent sphere placed in the opening.

207. The Choroid.—Inside the sclerotic coat is a thin vascular membrane, containing large numbers of

pigment-cells, called the choroid coat, or layer. (Fig. 102.) It lies against the inner surface of the sclerotic, and passes forward as far as the cornea. Here it be-

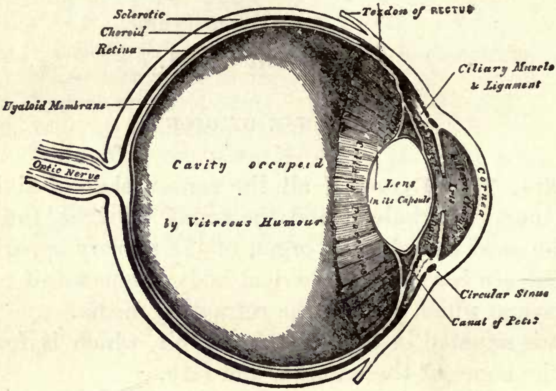

FIG. 101.—A vertical section of the eye, enlarged.

comes thickened, and forms the ciliary body, the inner surface of which is thrown into radiating folds, known as the ciliary processes. (Fig. 101.)

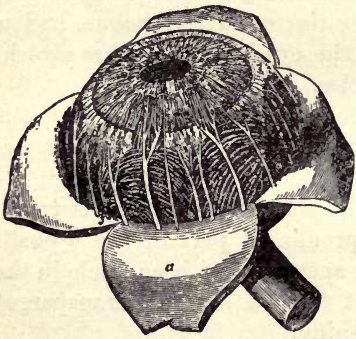

FIG. 102.—Showing the choroid coat by the removal of the sclerotic and the cornea: *a*, a segment of the sclerotic laid back.

To this ciliary body is attached the ciliary muscle, which has its origin at the point of union of the sclerotic coat and cornea. This little muscle is most important, for it is the chief means of focusing the eye on near or distant objects. (Fig. 103.)

The pigment-cells of the choroid are of a

dark brown or chocolate color, and absorb the rays of light which enter the eye.

Were it not for this, the light would be reflected to the various parts of the inner surface of the eye, and vision would be indistinct. This indistinctness is often experienced by persons who pass quickly from a dark room into a bright light.

Too much light enters through the dilated pupil, and objects are not distinctly seen for a moment, or there may be only the perception of a white, blinding light. The rays of light are too strong to be absorbed by the retina, and are reflected to various parts of the eye.

208. The Iris.—The iris is a thin muscular curtain suspended across the anterior part of the eye. (Figs. 101 and 103.)

It is continuous with the choroid, and its posterior surface is covered with the pigment-cells of the choroid.

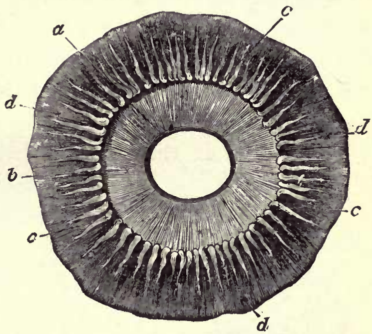

FIG. 103.—Showing the iris and the ciliary processes from behind: *a*, circular fibers; *b*, radiating fibers; *c*, ciliary processes; *d*, choroid.

These cells give color to the eye, it being black, brown, blue, or gray, according to the abundance and distribution of the coloring matter.

The iris has in its center a circular aperture, the pupil; this opening varies in size with the intensity of the light. This variation is due to the action of the muscular fibers of the iris.

There is a set of circular, or annular, fibers which contract the pupil when the light is too strong; and

opposed to this set of fibers are others which converge from the outer margin of the iris towards the pupil. These are known as the radiating fibers, and expand the pupil to admit more light.

209. The Retina.—The retina, the innermost coat of the eye, lies next the choroid, and extends forward as far as the ciliary body. (Fig. 101.)

The retina is thickest over the posterior portion of the eye. It diminishes in thickness as it passes forward, and disappears at the ciliary body.

This inner coat of the eye is the only part of the ocular apparatus which is sensitive to light.

It is very complex in composition, being made up of layers of nerve elements of various forms. There are ten distinct layers of this nervous matter, each of which has some action in exciting in the brain the phenomenon known as vision.

At a point in the fundus of the eye, directly opposite the pupil, is a light yellow spot about 2 millimeters ($\frac{1}{8}$ of an inch) in diameter, known as the "yellow spot" or the *macula lutea*. (Fig. 104.) In the center of this yellow spot is a small shallow depression, the *fovea centralis*, which is the point of most distinct vision. (Fig. 105.) Rays of light from an object towards which the eye is directed, enter

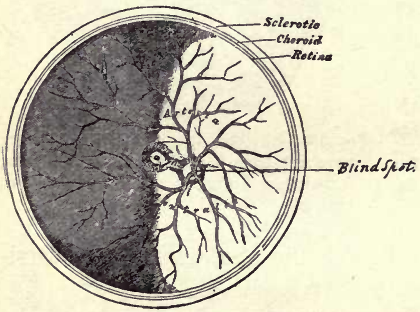

FIG. 104.—Showing the blind spot where the optic nerve enters the eye, the arteries and veins. The central dark spot is the *fovea centralis*.

the pupil in a direct line and are brought to a focus at this particular point.

Light which enters the eye at an angle falls upon other parts of the retina, and the figure and outline of objects from which such light comes are indistinct. The structure of the retina is changed over the *macula lutea*. The superficial or inner layers disappear, while the deep layer next the choroid, known as the layer of rods and cones, is augmented until at this point it forms the whole retina.

This would seem to show that the rods and cones form the part of the retina that is excited by rays of light.

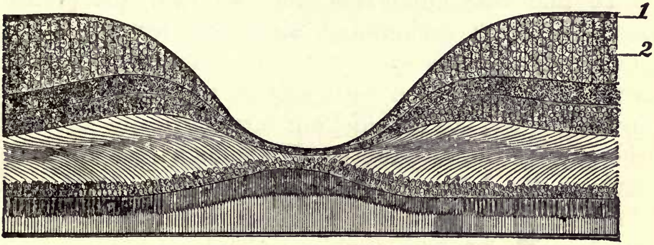

FIG. 105.—Section of the human retina through the *macula lutea* and *fovea centralis*: 1, inner surface of the retina; 2, ganglionic layer of nerve-cells. The depression in the middle is the *fovea centralis*.

210. The Blind Spot.—The optic nerve, which is the medium of communication between the eye and brain, enters the eyeball about 2.5 millimeters ($\frac{1}{8}$ inch) to the inner side of the *macula lutea*.

At this point of entry the retina is entirely absent and the nerve may be seen with the ophthalmoscope as a round, white, slightly prominent spot. (Fig. 104.) The artery and vein of the eye may also be distinctly seen at this point.

Although the optic nerve carries the sensation of light to the brain, the filaments which compose this nerve are insensible to light.

This point of entry of the nerve is known as the blind spot, for the light which falls upon this area is not perceived.

This defect in vision causes no inconvenience, because it is not in the line of direct vision ; rays of light coming from an object upon which the attention is fixed are never centered upon this part of the retina. More than this, rays of light which fall upon the blind spot in one eye must necessarily strike the sensitive part of the other eye.

If a person uses only one eye, there is always a part of the visual field that is not perceived.

To find this blind spot, let two cards be pinned against a dark background about two feet apart and on a level with the eye. Stand at a distance of about seven feet, and either card may be made to disappear by closing one eye and looking intently at the card on the side of the closed eye. If the right eye be used, look at the left-hand card, and the right-hand card disappears ; the opposite card disappears when the left eye is used, but both cards are plainly seen when both eyes are used. Impressions made upon the retina do not immediately disappear when the eye is closed or turned to some other object.

The impression of a bright light remains for an instant, if the eye be closed.

A rapidly revolving light appears as a luminous ring, just as the spokes of a swiftly moving wheel appear as a plain surface.

If a card be painted different colors and made to revolve rapidly, no color is distinct, but all are blended into one shade. These illustrations show that when an impression is made on the retina the effect lasts for a short time.

The object remains pictured upon the sensitive lining

of the eye for an instant when the eye is turned away or closed.

211. Color-Blindness.—The retina is sometimes incapable of distinguishing between colors. This is known as color-blindness, and in these days of danger-signals, when colors are used to indicate the presence or absence of danger, railroad men and mariners have to undergo examinations for this defect.

These are made by asking the person under examination to match certain bright colors. Red and green are the two colors most commonly confused, but in complete color-blindness the person is unable to distinguish shades of any color.

212. Humors of the Eye.—The eye is filled with two humors, which act as refracting media, and keep the coats of the eye distended.

That which fills the anterior or corneal portion is the aqueous humor, a thin watery fluid having about the same refracting power as water.

The posterior portion of the eye is filled with the vitreous humor, or body, which is a transparent jelly-like substance, whose power of refraction is somewhat higher than that of the aqueous humor.

The vitreous body is enclosed in a transparent, structureless membrane, which extends as far forward as the ciliary body. From this point it is known as the suspensory ligament. (Fig. 101.) It blends with the capsule of the crystalline lens, and holds it in position.

213. The Crystalline Lens.—Between the humors of the eye, just back of the iris, is the crystalline lens. (Fig. 101.)

This is a double convex, transparent, highly refractive body. Rays of light which enter the eye are refracted by it in such a manner that the image of any object in the field of vision is formed upon the retina.

The lens may be compared to a small-sized lemon-drop.

The anterior surface is less convex than the posterior. It is enclosed in a transparent capsule, which is continuous with the suspensory ligament. In the normal eye the lens is of sufficient power to focus rays of light on the retina. In this way the image of any object in view is formed upon the retina, and vision is made distinct. The image is always inverted, as in a camera. (Fig. 106.)

This may be shown by taking the eye of a white rabbit, the coats of which are transparent, and placing

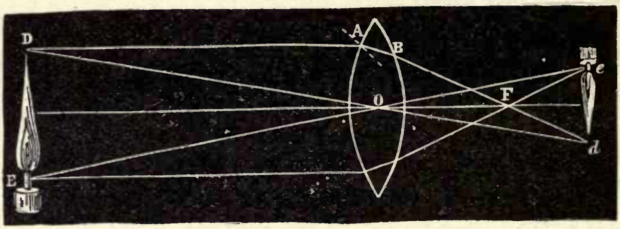

FIG. 106.—Illustrating the formation behind a convex lens of the diminished and inverted image of an object placed in front of it.

before it a lighted candle. The inverted image of the candle may be seen on the retina.

In the disease known as cataract the crystalline lens becomes opaque, and has to be removed so that light may enter the eye. After this is done it is found that the image of an object is formed at some distance behind the retina, is about four times as large, and is indistinct.

Thus it is shown that the lens brings the rays of light to a focus on the retina, and makes the image small, with clear, distinct outlines.

214. Power of Accommodation.—The focal distance of a lens changes according to the distance of the

object from the lens. This is best seen in a camera. The lens requires adjusting for each object before the light is allowed to fall on the sensitive plate, if a clear and distinct picture is to be obtained.

To overcome this change of focal distance the lens possesses what is called the power of accommodation. (Fig. 107.)

When the eye is at rest it is in a condition to receive impressions of objects at a distance. The rays of light

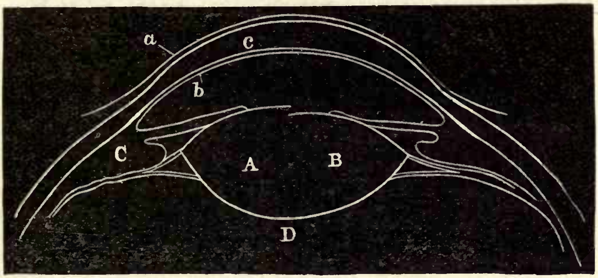

FIG. 107.—Section of the front part of the eyeball, showing the change in the form of the lens when near and distant objects are looked at: *a*, *b*, *c*, cornea; *A*, lens when near objects are looked at; *B*, lens when distant objects are looked at; *C*, position of ciliary muscle; *D*, space occupied by vitreous humor.

enter the eye as parallel, or nearly parallel, rays, and the image on the retina is sharp and clear.

Now, if the attention be directed to some object near at hand, the rays which enter the eye are divergent and the focal distance is increased.

In order to focus these rays on the retina, one or both of the surfaces of the lens must become more convex.

This is what really takes place in the eye.

The exact mechanism of the process is not understood, but through some action of the iris and ciliary muscle the anterior surface of the lens becomes more convex, and the rays of light are focused on the retina.

215. Near-Sightedness and Far-Sightedness.—If the lens be too strong, or if the antero-posterior diameter of the eye be too great, the rays of light are brought to a focus in front of the retina, and the image becomes blurred and indistinct. The eye is said to be *myopic,* or near-sighted.

If the opposite be true—the lens not strong enough, or the eye too short—the rays of light are focused back of the retina and the image is indistinct. This is known as the *hyperopic,* or far-sighted eye. (Fig. 108.)

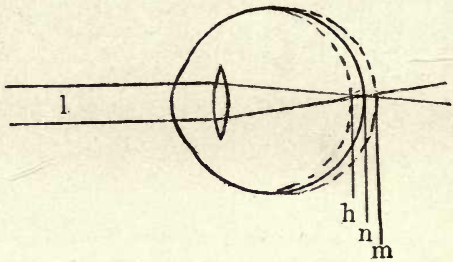

FIG. 108.—Showing the point at which the rays of light are focused in different eyes: *n*, the natural eye; *m*, myopic, or short-sighted eye; *h*, hyperopic, or long-sighted eye; *l*, rays of light.

To correct these defects glasses are used.

For myopia a concave lens is used, because it diverges parallel rays.

For hyperopia a convex lens is necessary, to bring the image forward to the surface of the retina.

216. Old-Sightedness.—When a person reaches the age of forty or forty-five his eyes begin to lose their power of accommodation.

The lens becomes firmer, and the iris and ciliary muscle fail to produce in it the changes necessary to properly focus near objects. Such a person holds a newspaper at arm's length to read, and fine print cannot be read.

Here convex lenses are necessary for perfect vision, when the object viewed is near at hand.

This defect is known as *presbyopia,* or old-sightedness.

217. Astigmatism.—It sometimes happens that there is a defect in one or both of the crystalline lenses, and the rays of light are so focused that an incorrect image is thrown on the retina.

This defect is known as astigmatism.

The image is distorted in various ways, and the eye often requires a combination of lenses to correct the difficulty.

218. Appendages of the Eye.—In order to protect this delicate organ it is placed in the deep bony socket, or orbit, formed by the bones of the face and skull.

In this cavity the eye is secure from injury except from the front.

Besides the eyeball, the socket contains the muscles which move the eye, a portion of the optic nerve, the nerves and vessels which supply the eye, connective tissue, and fat.

The eye is imbedded in these structures, and they act as a cushion for the delicate organ to rest upon, yet permit it to move freely in any direction.

219. The Eyelids.—The eyelids are so constructed that they may be shut over the front part of the eye and protect it from dust and small bodies which otherwise might do harm.

They are composed of thin plates of cartilage covered on the outer side with skin and on the inner side with a layer of delicate mucous membrane called the *conjunctiva.*

After passing backward over the inner surface of the lid this mucous membrane is reflected upon the eye, and covers the anterior part of the sclerotic and cornea.

The upper lid is larger than the lower and much more movable.

The lower lid raises but a trifle when the eye is closed, the upper lid being brought down to meet the free margin of the lower lid.

The margins of the lids, especially of the upper, are fringed with a row of hairs, or lashes, which protect the eye from too strong a light.

220. The Tears.—At the outer and upper part of the orbit is the lachrymal, or tear, gland. (Fig. 109.) This gland supplies the moisture which keeps the sclerotic and cornea from becoming dry and lusterless when exposed to the atmosphere.

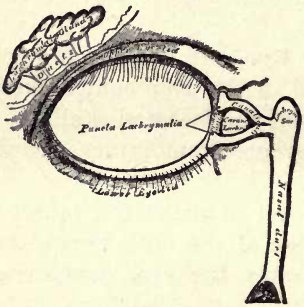

Fig. 109.—The lachrymal apparatus, showing the lachrymal gland and duct.

The flow from this gland is continuous, and the secretion is spread over the surface of the eye by the process of winking, which takes place without thought on our part.

Any irritation of the eye will cause an increase in the flow of the lachrymal fluid, which may overflow upon the cheeks.

Certain emotions, when excited, also produce an abundant flow from the gland.

The overflow from this gland is spoken of as tears.

Besides keeping the surface moist, the lachrymal fluid tends to wash out foreign particles from the eye.

The flow is from the outer and upper angle of the orbit downward across the eye to the inner angle, where the secretion passes into the nasal cavity through the nasal duct. (Fig. 109.)

This duct joins both the upper and lower lids, the point of opening being known as the lachrymal point.

This point can best be seen by pulling the lower lid down near the inner angle of the eye.

QUESTIONS ON SIGHT.

1. How does the eye compare with the other sensory organs?
2. Describe the sclerotic coat, the cornea, the choroid coat, the iris, the retina.
3. What is the *macula lutea?* the *fovea centralis?* the blind spot?
4. What proof have we that an impression made on the retina lasts for some time?
5. What is color-blindness?
6. What are the humors of the eye?
7. What and where is the crystalline lens?
8. How is the change of focal distance in the eye accomplished?
9. What is meant by myopia? by presbyopia? by astigmatism?
10. How may each of these defects be corrected?
11. What are the appendages of the eye?
12. What is the source and what is the use of tears?

CHAPTER XXIII.

THE SENSE OF HEARING.

221. The Sense of Hearing.—The sense of hearing is the sense through which we become conscious of sound, and recognize the pitch and quality of tones produced by resonant objects.

We distinguish between high and low tones, and between notes produced by a vibrating string and those produced by a reed, though the tones may be of the same pitch and intensity.

Some sounds also are pleasing to the ear, while others are harsh and disagreeable. We recognize people, without seeing them, by the quality of the voice; and we know the songs of different birds, and the cries of the various animals.

All sound is due to the vibrations of the atmosphere set in motion by mechanical means. These vibrations act on the organ of hearing in such a way that the endings of the auditory nerves are excited and the impulse is carried to the brain.

222. Organs of Hearing.—The ear is the organ through which the fibers of the auditory nerve are excited. (Fig. 110.)

This organ is divided into the external, middle, and internal ear. Each part of this apparatus has its function to perform.

The external ear is so placed and formed as to receive the wave-impulses, while the internal ear, with its delicate apparatus and nerve-endings, is deep within the

hard, flint-like portion of the temporal bone, where it is free from all mechanical impressions, except such as find their way through the external and middle ear.

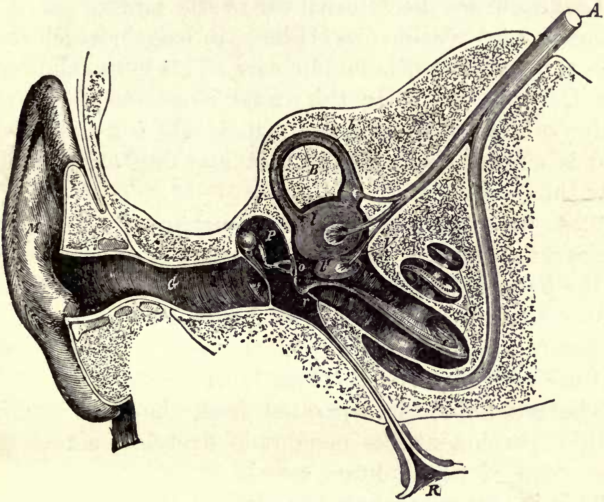

FIG. 110.—Semi-diagrammatic section through the right ear : *M*, external ear, or concha ; *G*, external auditory meatus ; *T*, tympanic, or drum, membrane ; *P*, tympanum ; *o*, oval foramen ; *r*, round foramen ; *T–O*, the chain of tympanic bones ; *R*, Eustachian tube ; *V*, *B*, *S*, bony labyrinth ; *V*, vestibule ; *B*, semicircular canal ; *S*, cochlea ; *b*, *l*, *l′*, membranous semicircular canal and vestibule ; *A*, auditory nerve dividing into branches for vestibule, semicircular canal, and cochlea.

223. The External Ear.—The external ear is composed of a shell-like framework of cartilage covered with integument. (Fig. 110.)

One is placed on each side of the head, the better to catch sounds coming from any direction.

In the lower animals the external ear is relatively much larger than in man.

It is also trumpet-shaped, and can be moved in various directions, so that its opening may be directed toward the point from which the sound proceeds.

In man the muscles which move the ear are rudimentary, and the power of motion, if it exists at all, is very limited.

Leading from the external ear to the middle ear is a canal about 3 centimeters (1¼ inch) in length, which conveys the sound to the middle ear. This is the auditory canal. (Fig. 110.) In this canal is secreted a yellow, bitter substance, the ear-wax, which acts as a lubricant, and is obnoxious to insects that may find an entrance into the canal.

224. The Middle Ear, or Tympanum.—The middle ear, or tympanic cavity, is an irregular-shaped cavity in the temporal bone.

It contains the ossicles, or bones, of the ear, and communicates with the throat through a canal known as the Eustachian tube. (Fig. 110.)

The middle ear is separated from the outer ear by a thin, parchment-like membrane stretched across the inner end of the auditory canal.

This is the *membrana tympani*, or the drum of the ear.

It receives impressions from the sound-waves in the auditory canal, and communicates these impressions to the ossicles, or bones, of the ear.

225. The Ossicles.—The ossicles consist of three small bones: the MALLEUS, or mallet; the INCUS, or anvil; the STAPES, or stirrup. (Figs. 110 and 111.)

These bones are very small, their entire weight being less than a gram (about .03 of an ounce), yet they have their blood and nerve-supply, are acted upon by the muscles, and are joined by ligaments as perfectly as the large bones.

The handle of the *malleus* is attached to the *membrana tympani*, and its head articulates with the *incus;* the *incus* is joined to the small end of the *stapes,* and

the large end or base of the *stapes* is inserted into an opening between the middle and internal ear (the *fenestra ovalis*).

In this way a complete chain is formed between the external and the internal ear. Sound-waves which enter the auditory canal strike the *membrana tympani*, and the impulse is communicated to the ossicles, and conveyed through them to the internal ear.

In order that an equal pressure may be maintained in the middle and external ear the Eustachian tube permits the passage of air to the middle ear. (Fig. 110.) This generally takes place during the act of swallowing.

This tube also allows the secretions of the middle ear to escape. If from any cause the tube becomes closed, sounds are muffled or indistinct. This is because the air is confined in the middle ear and does not vibrate readily.

226. The Internal Ear, or Labyrinth.—The internal ear is deeply seated in the temporal bone, and consists of three parts: a vestibule, or outer chamber; three small, semicircular canals; and the cochlea, or snail-shell. (Figs. 110, 112, and 113.)

227. The Vestibule.—The vestibule is an irregular-shaped cavity, into which the semicircular canals and cochlea open.

There is also an opening in the outer wall known as the *fenestra ovalis*, or oval window, into which is inserted the base of the *stapes*.

The auditory nerve also enters this cavity through openings in the inner wall. (Fig. 110.)

The vestibule is filled with a clear, limpid fluid, in which is suspended a double sac also containing fluid.

In the walls of these sacs the terminal fibers of the auditory nerve find an ending. There is also found

about the endings of the nerves a fine granular material, imbedded in a gelatinous substance, known as the ear sand. Its office is not understood, though it is probably important, for it is found in the ears of nearly all creatures.

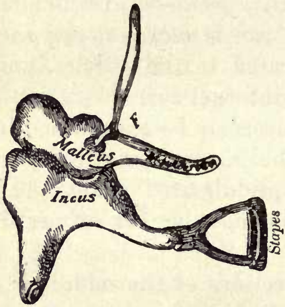

FIG. 111.—Ossicles of the right ear.

228. The Semicircular Canals. — The semicircular canals are three small channels, which take a half turn in the temporal bone. (Fig. 112.) The ends of each open into the vestibule, and these canals are filled with the fluid of the vestibule. They are arranged so that each canal is at right angles to the other two. In some way they are concerned in maintaining the equilibrium of the body. It is difficult to understand how these small semicircles can control the stability of the body, but when they are destroyed the effect is marked.

FIG. 112.—Bony labyrinth of the human ear magnified twice its natural size : *a*, vestibule ; *b*, superior vertical semicircular canal ; *c*, inferior vertical semicircular canal ; *d*, horizontal semicircular canal ; *e*, *fenestra ovalis* ; *f*, cochlea.

229. The Cochlea, or Snail-Shell. — The cochlea, or snail-shell, is a small spiral, which takes two and a half turns about a bony axis. (Fig. 110.) It is divided into two cavities by a shelf of bone which projects from the inner wall, and a membrane which extends from the free margin of this shelf to the outer wall of the cochlea. (Fig. 113.) Fibers

of the auditory nerve find an ending on the upper surface of this shelf.

230. Mechanism of Hearing.—Impressions are made on the drum of the ear, or tympanum, by sound-waves striking against the membrane. The vibrations of the drum communicate these waves to the chain of bones which extends across the cavity of the middle ear, and in this way the waves reach the internal ear, or labyrinth.

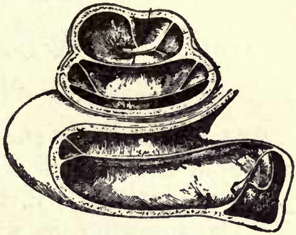

FIG. 113.—The bony and membranous cochlea laid open.

The fluid of the labyrinth is set in motion, and in some unknown way the filaments of the auditory nerve are excited, and a sound is heard. It is probable that the excitation of the nerve-fibers which end in the vestibule produces sonorous impressions only, while the filaments ending in the cochlea are those by which pitch and quality are recognized.

As many as three thousand terminal filaments have been counted in the cochlea.

QUESTIONS ON THE SENSE OF HEARING.

1. What do we learn through the sense of hearing?
2. What is the organ of hearing?
3. How is it divided?
4. What is the shape and purpose of the external ear?
5. What is the auditory canal? the Eustachian tube? the *membrana tympani?*
6. Describe the ossicles.
7. What are the divisions of the internal ear?
8. What seems to be the purpose of each of these divisions?
9. Give, in brief, the mechanism of hearing.

CHAPTER XXIV.

HYGIENE OF THE SPECIAL SENSES.—EFFECTS OF ALCOHOL.

231. Hygiene of the Special Senses.—"Half the wealth of the world is lost to most of us from lack of power to perceive."—E. Harrison.

"The time will come when it will seem as stupid, nay, as criminal to neglect the proper training of all a child's senses as to fail to teach him to read."—R. P. Halleck, M.A., *Education of the Central Nervous System.*

"The best preparation parents can give their children for good school training is to make them acquainted with natural objects, especially with the sights and sounds of the country."—President G. Stanley Hall.

Though the sense of touch is the simplest of all the senses, yet from it all the other senses were probably developed.

Exquisite delicacy of touch may be cultivated.

This is often illustrated by blind people, and such examples as Laura Bridgman and Helen Kellar show how touch may almost be made to take the place of the other senses.

The ability to see and hear is improved by cultivating attention and concentration. By careful training and use the organs of sight, hearing, smell, and taste may be developed; by neglect or misuse they may be permanently injured.

No one of the organs of sense should be used after it becomes fatigued.

This direction applies with special force to the use of the eyes. They should not be used for reading or studying with too faint or too dazzling a light.

The light should not fall directly upon the eyes, but should come from one side or from over one shoulder, preferably the left.

Reading in a reclining position, or on a train, strains the eyes.

"So long as the eye does not err and remains free from fatigue in the work required of it, its own power is sufficient, and it is inexpedient to seek assistance in the use of convex glasses. . . . The ophthalmic surgeon is the one to be consulted as to the wearing of glasses. He, by testing the eye, can alone decide whether any, and what, glasses should be worn."—Dr. B. Joy Jeffries.

Simple tests of eyesight and hearing may be given to advantage in the school-room, and it will often be found that dullness and inattention on the part of pupils is the result of defective eyesight or of slight deafness.

Care should be taken not to injure the ear by lowering its temperature through the introduction of either cold water or cold air.

There is danger of injury to the drum of the ear by the introduction of sharp metallic substances for the removal of ear-wax.

The ear-drum may be ruptured by a sudden blow or a loud noise.

232. Effects of Alcohol on the Special Senses.— All the nerves of special sense suffer from the narcotic influence of alcohol.

Vision is most susceptible to this influence. The bleared eyes of the drunkard are proverbial.

Double vision is one of the first signs of intoxication.

In *delirium tremens* the eye seems to see terrifying creatures which do not really exist.

"Many physicians believe that cataract and retinal diseases may be produced by drinking."—H. Newell Martin, M.D.

"Experiments made by Dr. Scougal upon the sense of hearing show that alcohol in small quantities affects this special sense in the same way as the other organs of special sense are affected by it."—*School Physiology Journal.*

"Disorder of the nerves of taste creates a desire for strong alcoholic beverages which nothing else will satisfy."—Edward C. Mann, M.D.

"Fine penmanship or drawing, and the use of keen-edged tools depend upon a delicate employment of touch; but with a hand that shakes like the palsied limb of an aged man this becomes an impossibility."—Hutchison.

"The senses of sight, hearing, taste, and smell are often involved in the anæsthetic form of nervous disease from alcohol."—Dr. Hammond's *Diseases of the Nervous System.*

EXPERIMENTS ON THE SPECIAL SENSES.

1. Experiments, under the sense of touch, illustrating the common sensations conveyed through the skin, will readily suggest themselves to the teacher.

The sensation of temperature, which some physiologists count as a sixth sense; that of weight, sometimes called the muscular sense, and that of pain may be illustrated with material at hand.

The attention of pupils should be directed to other common sensations, as hunger and thirst, drowsiness, fatigue, and satiety.

2. Attention may be directed to the papillæ of the tongue and experiments may be made showing what part of the tongue is most sensitive to sweet, sour, and bitter substances.

The help which the sense of taste receives from the senses of sight and smell should be illustrated by closing the eyes, stopping the nostrils, and tasting various substances.

3. All the special senses may be developed by training.

Kindergartners recognize this fact.

The sense of smell may be cultivated by requiring a child to distinguish different odors with the eyes closed.

Teach pupils how to cultivate the different senses, and help them to make lists and collections of objects for sharpening the senses of touch, taste, and smell.

Reuben Post Halleck, in his *Education of the Central Nervous System*, gives lists of objects for cultivating the special senses.

The following list of objects for cultivating the olfactory sense is copied from him:

Pennyroyal,	Caraway,	Gum benzoin,
Orris root,	Chamomile,	Valerian root,
Sage,	Black pepper,	Ginger root,
Cinnamon,	Red pepper,	Gum turpentine,
Cloves,	Celery seed,	Assafœtida,
Licorice,	Fennel,	Myrrh,
Sassafras,	Saffron,	Star anise,
Allspice,	Lavender flowers,	Tonka bean,
Cardamon,	Manna,	Olibanum,
	Gum Arabic.	

Pupils should of course be blindfolded when undergoing the tests.

For cultivating the sense of touch he suggests: "It is fine practice to study the leaves of the more common forest trees with the aid of both the eye and the hand. After the leaves are familiarly known by the aid of both the senses, the pupil should be blindfolded and asked to identify by touch the leaves of the elm, maple, chestnut, hickory, black walnut, oak, dogwood, birch, beech, sycamore, willow, pine, larch, hemlock, cedar, and whatever other trees are found in the neighborhood."

4. An eye should be obtained and dissected before the class.

Show the pupils a camera and explain its different parts and their uses.

Illustrate the uses of concave and convex lenses.

5. Tests of hearing and sight may be made by the pupils themselves at the teacher's suggestion.

CHAPTER XXV.

THE VOICE.

233. Voice.—Nearly all animals possess the power of expressing their feelings by means of a special apparatus situated at some point within the respiratory tract.

How much communication is carried on by the lower animals is not known, but we see them rally at a cry of distress, and show satisfaction at the evident enjoyment of their fellows.

The utterances of human beings are spoken of as the voice, and the expression of ideas by means of the voice is called speech. The voice is used, as in the lower animals, to express the various emotions dependent upon external influences and environment. More than this, man reasons, and by the faculty of speech can explain conclusions reached.

This power of expressing thought exists only in man.

The parrot and raven can be taught to speak words, and even sentences, but the speech is irrelevant and entirely automatic.

The idiot has a perfect set of vocal organs, and can utter loud cries ; but his speech is fragmentary, unconnected, and devoid of reason.

234. Relation to Hearing.—There is a close relationship between speech and hearing, for it is through the sense of hearing that we learn to understand the meaning of sounds, and to produce them. A child can produce sounds, but it cannot make its wants known

by speech until it learns words, and understands their meaning. Children who are born deaf never learn to speak unless trained to imitate the motions of the lips and tongue; and when speech becomes possible, the

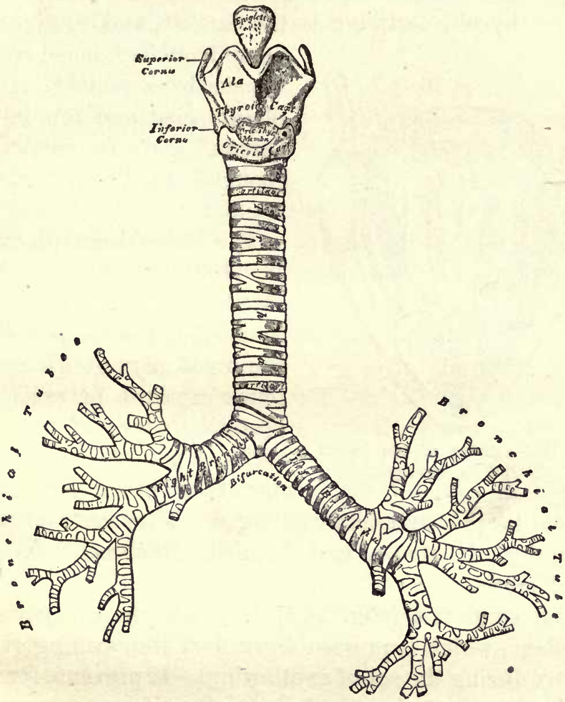

FIG. 114.—Front view of the larynx, epiglottis, trachea, and bronchi.

voice is harsh, for the ear gives no idea of the quality of tone. Persons with impaired hearing also speak in a peculiar way; the voice is raised and lacks purity, and sentences are spoken in a harsh monotone.

235. Vocal Apparatus.—The vocal apparatus of man is situated at the upper end of the trachea, and consists

of a cartilaginous framework, the larynx (Fig. 114), and the vocal cords.

The cartilages which compose the larynx are five in number: the thyroid, cricoid, two arytenoid, and the epiglottis. (Fig. 115.)

The thyroid cartilage is the largest, and receives its name from its fancied resemblance to a shield. It is plainly seen and felt in the throat, and is commonly spoken of as "Adam's apple."

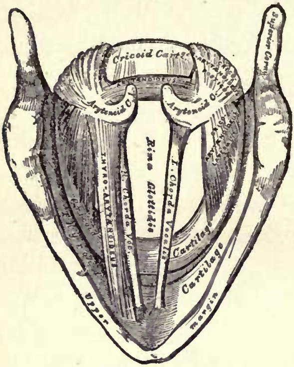

FIG. 115.—Interior of the larynx, showing the cartilages.

The cricoid cartilage is situated below the thyroid cartilage, and is shaped somewhat like a seal-ring, the broad part of which extends upward between the posterior edges of the thyroid. Upon the upper border of this broad part of the cricoid lie the arytenoid cartilages. They are somewhat pyramidal in shape, and furnish attachment for the vocal cords.

The epiglottis (Fig. 114) is a leaf-shaped piece of cartilage, which is pressed down over the opening of the larynx during the act of swallowing. It prevents foreign bodies from entering the laryngeal cavity.

These cartilages are bound together by ligaments and bands of connective tissue in such a way that they move upon each other during respiration and phonation.

The cavity of the larynx is lined with a very sensitive layer of mucous membrane, any irritation of which causes violent coughing.

236. The Vocal Cords.—The true vocal cords are

bands of connective tissue, which are attached to the posterior surface of the thyroid cartilage, and extend across the opening of the larynx to the arytenoids. They are covered by the mucous membrane which lines the larynx, and this membrane is firmly adherent to them, making their free margins sharp and even. (Fig. 115.)

Lying above the true cords are folds of mucous membrane which closely resemble them, and are known as the false cords. They have nothing to do with the production of sound, and take their name from their resemblance to the true cords.

237. Muscles of the Larynx.—There are several sets of muscles attached to the larynx which act in such a way that the vocal cords are approximated, or separated, and made tense, or lax. (Fig. 115.) This gives range to the voice.

When the cords are lax and the margins separated, the note is low; when tense, and their edges close together, the note is high. (Fig. 116.) The movements of the larynx during respiration are due to the action of these muscles. The opening between the cords widens with each inspiration, and narrows with each expiration.

238. Production of Vocal Sounds.—Sounds of varied pitch and intensity may be produced by forcing out the air contained in the lungs between the free margins of the vocal cords.

The pitch will depend upon the tenseness of the cords, and the loudness upon the volume of escaping air.

The sounds are due to the vibrations of the free margins of the vocal cords. The same result is obtained in reed instruments by confining air in a bellows and allowing it to escape through reeds, the tongues of which vibrate in the escaping air.

The quality of tone which distinguishes one voice

from another depends upon the formation and resonance of the throat, mouth, and nasal passages.

The teeth, lips, and tongue are useful in producing the sounds of the consonants. In the case of people who have lost their teeth, or have what is known as a "hare-lip," it may be plainly seen how much these parts have to do with the production of certain sounds. The tongue is not so important in vocalization, for persons

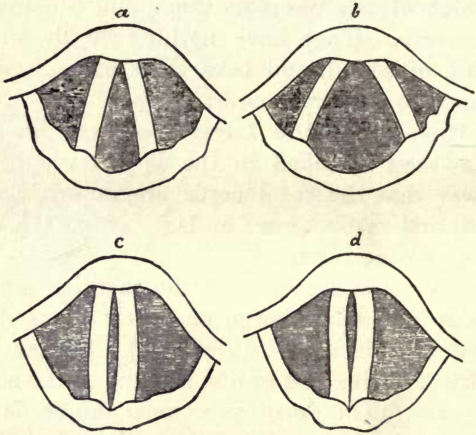

FIG. 116.—The vocal cords: *a*, position of rest; *b*, position during inspiration; *c*, position during speaking ("chest voice"); *d*, position during speaking (falsetto voice).

who have lost a part, or the whole, of this organ, can still speak so that they are readily understood.

239. Varieties of the Voice.—There are four varieties of the voice.

In the female, the voice is said to be soprano or alto; in the male, tenor or bass. There is also a variety of the female voice—the mezzo-soprano—which combines the qualities of both soprano and alto; and a variety of the male voice—the baritone—which combines the qualities of both tenor and bass.

During childhood and early youth the voice is the same in both sexes, usually a light soprano. At the age of fourteen, or thereabouts, the voice is said to change.

This change is due to an increase in the size of the larynx, which takes place at this time. It is not very noticeable in the female, but in the male the larynx nearly doubles its size during the changing period. The vocal cords become larger and longer, and the voice changes from a light soprano or alto, to a tenor or bass. While these changes are occurring the voice should be used with care, for any straining of the vocal cords at this time may permanently injure it.

The ordinary range of the voice is about two octaves but with training this range may be extended, and the quality of tone greatly improved.

Many opera singers can command three full octaves, and the precision and rapidity of action of their laryngeal muscles are wonderful. It is said that Mme. Parepa-Rosa's voice, because of its purity and strength, was distinctly audible in a chorus of twelve thousand voices and an orchestral accompaniment of a thousand instruments.

With training, the voice becomes flexible, and the power of execution increases. The tones become flute-like, and possess all the purity and precision of the bird.

This is especially true of the soprano voice. The alto also attains great perfection, and the tenor and bass may gain in purity and strength, but they never attain the proficiency of execution of the female voice.

240. Ventriloquism.—Some persons possess the ability of making the voice sound as though it came from a distance.

They can imitate a call coming from a person high in the air, or the muffled cry of a voice beneath the earth.

Such a piece of mimicry is often startlingly correct, and is used largely for purposes of entertainment. The

performer moves his lips but slightly, and, at the same time, directs the attention to a point from which the sounds seem to come, and often the illusion is complete.

It was formerly supposed that the ventriloquist possessed a special vocal apparatus, but it is now known that the sounds are produced in the ordinary way, and the success of the performance is due very largely to the power of mimicry possessed by the performer. The person, in order to be successful, must be able to imitate the various animals, talk in several tones of voice, and fix the attention of the audience on some other object than himself.

QUESTIONS ON THE VOICE.

1. Define voice and speech.
2. What is the use of voice in the lower animals and in man ?
3. What is the relation between speech and hearing ?
4. Of what does the vocal apparatus consist ?
5. What cartilages compose the larynx ?
6. What are the vocal cords ?
7. Of what use are the laryngeal muscles ?
8. Upon what do pitch of voice and quality of tone depend ?
9. What are the varieties of voice ?
10. To what is the change of voice due ?
11. What is the ordinary range of the voice ?
12. What is ventriloquism ?

CHAPTER XXVI.

COMMON AND CONTAGIOUS DISEASES.

241. Disease-Germs.—Of late years the careful study of disease has revealed the fact that nearly all, if not all, sickness is due to certain specific germs which find lodgment in the system, and by their presence cause distinct and definite disturbances.

The germs which cause the eruptive fevers—such as typhoid and scarlet—measles, diphtheria, etc., have all been carefully studied, and their mode of infection ascertained.

With the increase of knowledge concerning the growth and development of disease-germs, sanitary rules have been perfected which prevent, in large measure, the spread of infectious diseases. These rules are so effective that for some time the plagues which are so destructive in many of the cities of Europe and the East, have been unable to gain a foothold in this country.

A few isolated cases now and then appear, but they are quickly stamped out.

How to prevent the infectious diseases which prevail in our midst is the great question before the medical profession of to-day. When once these diseases become epidemic, constant care and watchfulness are required to prevent their spread from house to house, and from one member of a family to another.

To prevent epidemics great care should be taken to obtain pure water, pure milk, and perfect ventilation.

Sewage should be carefully disposed of, and the streets kept clean.

242. Typhoid Fever.—Typhoid fever is not a disease that is directly transferable from one person to another. In popular phrase, it is not "catching." It is conveyed largely in drinking-water, the germs finding their way by this means into the stomach and intestines. They pass from the system, and, to prevent the further spread of the germs, the excreta, together with all soiled bed-linen, should be thoroughly disinfected. (A solution of corrosive sublimate, one part to one thousand parts of water, is an effective disinfectant.)

243. Scarlet Fever.—The germs of scarlet fever are taken into the system through the air-passages. They are in or upon the outer layers of the skin that peel from the body during the later stages of the disease. This is known as the "peeling process," and as the fine scales may float about in the air they easily find lodgment in the throat and air-passages.

The disease is less contagious during its development, yet the patient should be isolated from the first. The skin should be kept oiled after peeling begins to prevent the fine scales from floating about in the air. A sheet or blanket wet in an antiseptic solution may be hung over doors.

The nurse should not be allowed to mingle with members of the family, and before the person who has been sick is allowed to leave the sick-room, an antiseptic bath should be given him.

The room and contents should also be thoroughly cleansed and fumigated.

244. Diphtheria.—This disease, like scarlet fever, is directly communicable. The germs are probably in the discharges that come from the throat and air-passages and they should all be thoroughly disinfected or, better yet, burned.

Cloths used to catch sputum and mucus should be

burned before they are allowed to dry, so that the germs may not float about in the air. Careful isolation from the first is imperative, and the room, with its contents, should be carefully and thoroughly fumigated.

245. Measles, Mumps, and Chicken-Pox.—These diseases are all transferable from one person to another, but they are much less serious than the preceding, and their presence in a community does not rouse the fear and anxiety that an epidemic of diphtheria or scarlet fever does. They should be avoided, for they may result in changes in some of the organs of the system that will cause serious inconveniences through life.

246. Rules for Fumigation.—Sulphur is one of the best germicides, is the easiest managed, and does no harm to furniture or fabrics. It should be burned, and the fumes allowed to remain for several hours with all doors and windows tightly closed.

Two to four pounds should be burned in an ordinary room.

It is best to place it in an iron or tin dish and set this inside a tub containing a small amount of water. If it flies over the edge of the dish, the burning particles are extinguished in the water.

A small amount of alcohol may be poured over the sulphur to facilitate combustion.

No attempt should be made to enter the room while the sulphur-fumes are present, for breathing is impossible, and irritation of the throat and air-passages may result.

247. Consumption.—Consumption is due to the lodgment and growth of germs (*bacilli tuberculosis*) in some organ of the body.

The lungs and larynx are the most frequent seats for their development, because the germs find easy lodgment at these points; but the bones, the intestines, the mem-

branes covering the brain—in short, almost any part of the body may be the seat of the disease.

The disease prevails in all climates and attacks all races.

It is perhaps the most prevalent of all diseases, and it has been estimated that one-seventh of all deaths is due to its ravages.

Like measles, scarlet fever, etc., it is exclusively a germ-disease, and would be stamped out with the destruction of all the bacilli.

Sputum-cups, handkerchiefs, and clothing should be kept scrupulously clean, and the sputum should be burned.

The curtailing of this terrible disease is largely in the hands of the people; it can be accomplished only by constant care and watchfulness. Physicians may give directions and furnish the means, but attendants become careless, the sick ones are not always careful, and thus other members of the family may contract the disease.

Persons who are predisposed to consumption should not care for those sick with the disease, and should certainly not sleep with them nor be much in the sick-room.

"A very eminent authority, the late Dr. Marshall Hall, of England, said, in reference to pure air in the treatment of consumption: 'If I were seriously ill of consumption, I would live out doors day and night, except in rainy weather, or in midwinter; then I would sleep in an unplastered log house. Physic has no nutriment, gasping for air cannot cure you, and stimulants cannot cure you. What consumptives want is pure air, not physic—pure air, not medicated air—and plenty of meat and bread.' Let it be remembered, in this connection, that every hygienic or health-promoting measure which tends to cure a disease is much more efficacious in preventing it."—Black's *Ten Laws of Health.*

CHAPTER XXVII.

EMERGENCIES.

"The readiness is all."—*Hamlet.*

248. Emergencies.—It not infrequently happens that medical or surgical aid cannot be immediately obtained in case of accident, fainting, convulsions, etc., and every one should know how to render assistance at such times.

249. Fainting.—Fainting is a common occurrence in crowded rooms where the air is impure and heated. The fainting person should be taken into the fresh air and fanned, the face bathed with cold water, and rest and quiet enjoined.

The recumbent position is best, though not absolutely necessary unless the faint is prolonged.

250. Convulsions.—Convulsions due to epilepsy require little or no treatment except to keep the person from harming himself.

Protect the head by putting a pillow or a cushion under it; crowd something, the corner of a folded handkerchief or a cork, between the teeth to prevent the biting of the tongue.

Although the appearance is distressing, the convulsive movements soon cease and consciousness returns. Rest and quiet should be had, if possible, and the person be allowed to sleep.

Bathing the face and hands will help to restore consciousness.

If convulsions occur in children, they should be given a hot bath (care being taken that the water be but little above blood-heat, about 98° Fahrenheit) and rubbed. Ground mustard may be added to the water.

Keep them in the bath ten or fifteen minutes, then wrap them in blankets and put cool applications on the head.

251. Suffocation, or Asphyxia.—In case of suffocation, the first thing to be done is to remove the person into the open air, loosen the clothing, dash cold water on the face and neck, and, if necessary, employ artificial respiration. (Section 270.)

If you are in a vat, well, or cellar where there is carbon dioxid, stand up. The gas is heavier than the air and sinks. Before descending into old wells, etc., it is well to test the air by lowering a lighted candle; if it be extinguished, the place is not safe.

252. Sunstroke.—Sunstroke is due to an unnatural rise in the temperature of the body caused by exposure to the rays of the sun. There is loss of consciousness, high temperature, and a dry skin, in cases of sunstroke. Remove the clothing; apply broken ice to the head; rub ice on the chest and lay it under the arms. The purpose is to lower the temperature. If ice be not at hand, wrap the patient in sheets wet with cold water.

253. Heat-Exhaustion.—Heat-exhaustion is caused by confinement in close, hot rooms, like work-shops, basements, etc. If the temperature be low, the skin cold and clammy, cold applications should not be made. Give the patient fresh air, hot drinks, if possible, and apply heat to the body to raise the temperature.

Both sunstroke and heat-exhaustion may be followed by serious results, and persons who have once suffered from either are more liable to a second attack.

254. Fractures.—If a bone be broken or a joint dis-

located, the person should be put in as comfortable a position as possible and kept quiet until a surgeon can be summoned.

If it becomes necessary to move the person, the injured part should be handled with great care and gentleness, that the flesh and skin about the injury be not lacerated or broken, producing what is known as a compound fracture. Too much care cannot be exercised under these conditions, for if a sharp fragment of bone be thrust through the skin, the injury is made very much more serious, and may result in the loss of the limb, or even of life.

"If injured persons have to be moved from one place to another, it is worth while to know how to do it with the greatest ease and safety to them. If a door, or a shutter, or settee, is at hand, any of these will make a good litter, with a blanket, or shawls, or coats, for pillows. In lifting a person upon a stretcher, it should be laid with its foot at his head, so that both are in the same straight line. Then one or two persons should stand on each side of him, and, raising him from the ground, slip him upon the stretcher. This can be done smoothly and gently; whereas, if a stretcher be laid alongside of an injured person, some of those who lift him will have to step backwards over it, and in so doing are very apt to stumble. If a limb is crushed, or broken, it may be laid upon a pillow, with bandages tied round the whole, so as to keep it from slipping about. . . . When no litter can be gotten, the body may be supported by a man on each side, with their arms placed behind his chest and under his hips. In carrying an injured person upon a litter, or what serves for one, the bearers ought not to keep step; but when they are not using a litter, they should keep step."—Dulles's *Accidents and Emergencies,* from Blaisdell.

A broken leg or arm may be bound, by strips of clothing or handkerchiefs, to a piece of board, pasteboard, a cane, or a shingle, padded with cotton, grass, or moss, as a temporary splint.

When possible, the arm should be put into a sling after the splint is adjusted.

A broken leg may be bound to the uninjured one above and below the injured parts, so that the uninjured leg may serve as a splint for the broken one.

255. Hemorrhage.—In injuries, such as cutting and laceration of the fleshy parts of the body, a person may die from the loss of blood. If the bleeding be internal, very little can be done, except to enforce quiet, and apply such stimulants as may be had.

The head should be lowered, the body protected from the air as much as possible, and the clothing loosened.

If, however, the bleeding point can be seen, the hemorrhage can usually be controlled. Bleeding from the capillaries and veins can be stopped by applying moderate pressure. (Section 111.)

Strips of a handkerchief, or cotton wadding, may be crowded into the wound to keep up the pressure.

If an artery be severed, the flow of blood is sometimes difficult to control. A cord, or handkerchief, may be twisted tightly around the limb between the hurt and the body, or, if this cannot be done, a firm, strong pressure over the bleeding vessel may be made with the fingers, and the bleeding controlled until surgical aid can be obtained.

For injuries to the fingers and hand, press on the bleeding spot, or just above and in front of the wrist.

For injuries below the elbow, direct pressure should be applied to the upper part of the arm. Tie a knotted cord over the artery which runs in the middle line of the bend of the elbow.

For the upper arm, press with the fingers on the inner side of the biceps muscle, and twist tightly a knotted cord, or handkerchief, with a stick, bringing the knot over the artery.

For the foot or leg, pressure should be made in the hollow behind the knee, above the calf of the leg. Double the thigh up against the body, and bind the leg to the thigh.

If the femoral artery be cut, pressure should be applied to the groin about two-thirds of the way forward from the hip-bone.

256. Hemorrhage of the Lungs and Stomach.—Blood which comes from the lungs is bright scarlet and frothy, or "soapy," and tastes salty. Very little can be done in such cases of bleeding, except to enforce quiet and apply such stimulants as may be had.

Bits of ice should be taken freely.

Blood from the stomach is dark, has a sour taste, and is not frothy. Keep the person flat on his back and follow the directions given above.

257. Bruises and Cuts.—For bruises apply ice-cold water first, then as hot water as can be borne.

In the case of cuts or ragged wounds, cleanse the parts thoroughly, bring the edges together, and put on narrow strips of court-plaster. Do not cover wounds with court-plaster, but leave room for the escape of the pus.

Wounds made by toy pistols, rusty nails, etc., must not be neglected. They should be kept clean.

Often hot fomentations are all that is needed, but sometimes poultices of flaxseed, etc., are necessary.

258. Burns and Scalds.—The pain which accompanies burns and scalds is often excessive. This may be controlled, or greatly relieved, by applications which keep the air from the injury.

Cloths dipped in a solution of baking-soda (two or more tablespoonfuls of soda to a quart of water) and applied to the burn will relieve the pain. The application is cooling and grateful, and removes the smarting and soreness.

Vaseline, or olive oil, or any bland ointment may be applied later. "Carron oil," which is composed of equal parts of lime-water and linseed oil, is a favorite remedy in foundries and iron-works, where burns are frequent.

If a third or fourth of the surface of the body be burned, the injury often results fatally.

Scars may be left, if the healing process be too rapid.

If a person's clothing takes fire, do not allow him to run, as that only fans the flames. Throw him down and roll him in blankets, rugs, coats, or any woolen article you can find to smother the flames.

If nothing be at hand, roll him over and over, at the same time beating out the fire.

If you are in a burning building, keep as near the floor as possible to avoid suffocation from the smoke, and crawl to the door or window. If possible, wrap wet cloths about the head.

259. Foreign Bodies in the Air-Passages.—Portions of food may sometimes pass into the larynx during the act of swallowing, and cause much distress. The opening in the larynx closes spasmodically, the face turns livid, and suffocation is threatened. Small objects, such as pins or tacks and the like, when placed in the mouth may inadvertently slip into the larynx and pass to the trachea, and even to the bronchial tubes.

A sharp blow on the back is often sufficient to dislodge the object, though it may sometimes be necessary to hold the person up by the heels, and shake and slap

the body sharply before the foreign substance can be ejected. Emetics may be given, though they are of little use in these cases.

260. Poultices: When and How to Use Them.—A poultice, if intelligently applied, may give great relief from severe pains in the chest, abdomen, and elsewhere.

To make a mustard paste, mix an even tablespoonful of mustard and three or four tablespoonfuls of fine flour with enough water, or vinegar, to make a smooth paste. Spread it neatly on a piece of soft linen, or muslin; cover the face of the paste with a thin piece of muslin, or linen, and apply to the seat of pain.

Some skins are very sensitive; therefore the paste should be watched. About twenty minutes is long enough to keep it on; and whenever the skin looks red and smarts badly, the paste should be removed at once.

Do not put mustard pastes on young children.

If you do not want the paste to raise a blister, mix it with the white of an egg instead of water or vinegar.

To make a poultice of flaxseed, oatmeal, ryemeal, or slippery-elm, stir slowly into boiling water until a smooth paste is formed. Then fold a piece of muslin, or linen, in the middle, spread the poultice on one half of the cloth, and cover it with the other half.

Apply as hot as it can be borne. Never let a poultice get cold. Keep hot ones to exchange for the cold ones.

Flannels wrung out of hot water, cloths heated, rubber bags filled with hot water, are useful to relieve cramps, pains, injuries, or sprains.

261. Poisoning.—All medicines in bottles or paper packages should be carefully labeled. Many an accident is due to a dose of medicine taken by mistake.

All poisons should be put into bottles plainly labeled, and the word "POISON" should be printed or written across the label.

Never use any medicine unless you know what it is.

Whenever an irritant poison has been swallowed, a physician should be summoned at once. In the meantime vomiting should be induced, if possible. This may be accomplished by giving ipecac, or the following preparation : put a heaping tablespoonful of ground mustard, or of common salt, into a pint of warm water, and give a cupful every ten minutes until vomiting results. Another good emetic is two teaspoonfuls of powdered alum stirred into two tablespoonfuls of syrup. Give a tablespoonful every ten minutes until vomiting is induced.

Keep cool, act promptly and vigorously. Keep up the vomiting by copious draughts of warm water, flaxseed tea, or any mucilaginous drink, or by tickling the throat with the finger or a feather, until you are sure the poison is expelled from the stomach.

262. Poisons.—Poisons may be divided into the following general classes : Acid, Alkali, Mineral, and Narcotic.

263. Acids.—This class includes sulphuric acid (oil of vitriol), nitric acid (aqua fortis), muriatic acid (spirits of salts), oxalic acid, and carbolic acid.

If any of these poisons be swallowed, alkalies should be given. Soapsuds, baking-soda, lime-water, or whitewash or lime taken from the walls.

If carbolic acid has been taken, give soapsuds mixed with some form of oil—olive, or sweet, oil is best. Follow with copious draughts of oil or milk.

Oxalic acid resembles Epsom salts or granulated sugar.

The antidotes for this poison are chalk, whitewash, etc., given in warm water.

264. Alkalies.—The most common alkalies and their salts are ammonia (or hartshorn), potash, soda, pearlash (carbonate of potassa), and saltpeter (nitrate of potassa).

The antidotes for these poisons are acids.

Give vinegar, lemon juice, the raw whites of eggs, milk in large quantities, sweet oil, linseed oil, or castor oil.

265. Mineral Poisons.—Arsenic, Fowler's solution, Paris green, sugar of lead (acetate of lead), white lead (carbonate of lead), copperas (sulphate of iron), blue vitriol (sulphate of copper), corrosive sublimate (bichlorid of mercury), and lunar caustic (nitrate of silver) are all in common use.

The best antidotes for mineral poisons are large quantities of milk, raw whites of eggs, flour and water, oil and lime-water, or flaxseed-tea.

The object is to produce vomiting, as in the case of acid poisons.

Children sometimes eat phosphorus from matches.

When this happens, give chalk, magnesia, or whiting, but no oil.

266. Narcotic Poisons.—This class of poisons includes opium in its various forms (laudanum, paregoric, soothing syrups, cholera mixtures, etc.), belladonna, hemlock, digitalis, nux vomica, strychnin, and aconite.

Antidote: Call a physician immediately, and give emetics, as mustard or alum, prepared according to the directions given in section 262.

Give clear, strong coffee; dash cold water over the head and shoulders, and slap the skin with the hand, or with wet towels.

Keep the patient in motion, for under no circumstances must he be allowed to go to sleep.

If strychnin or nux vomica has been taken, chloroform or ether may be used to quiet the spasms.

267. Stings.—For the stings of insects, cloths wet in ammonia, carbolic acid, or soda water may be applied.

Sometimes mud applied to the wound will give relief.

268. Fish, Eels, Crabs, etc., and Canned Goods.—When persons are poisoned by eating these foods, emetics (section 262) should be given; also a purgative, such as castor oil. Vinegar and warm water may be drunk freely at the same time.

269. Drowning.—The method of performing artificial respiration in cases of unconsciousness due to immersion should be well understood, for it is the most efficient means of restoration that can be used.

Attempts should be made to revive a person when the immersion has not exceeded twenty minutes. The body should be inverted to allow the water with which the lungs are filled to escape, and then placed on the back with the shoulders elevated.

The operator, kneeling at the head, should grasp the forearms between the wrists and elbows, bringing the arms above the head until the hands meet. This expands the chest-walls and draws air into the lungs. The arms should then be lowered and pressed against the chest-walls to expel the air.

These movements should be repeated from eighteen to twenty times a minute, and continued for half an hour, unless natural respiration be sooner established.

While artificial respiration is being performed, the body and lower extremities should be briskly rubbed to re-establish circulation, if possible. As soon as the person can swallow, hot tea, coffee, milk, etc., should be administered, and heat applied to the body and extremities. Do not cease your efforts if you perceive no signs of life after working half or three-quarters of an hour, for persons have been resuscitated after lying unconscious for one or two hours; therefore do not be easily discouraged.

270. The Care of the Sick-Room.—The sick-room should be the sunniest and best ventilated room in the

house. It should be on an upper floor, and, in case of contagious diseases, as far removed from the family as possible.

The air should be kept pure, for sunlight and fresh air are more efficacious than drugs. An open fireplace is a great help in keeping the air pure; but windows should be kept open for the inlet of fresh air.

Great care must be exercised to keep the patient out of draughts. This can be done with screens, or by covering the person while the room is being aired.

Remember that cold air is not necessarily pure air, and that creating a current by means of fans, or by swinging doors, is not purifying the air. Often it disturbs and tires the patient.

Keep the room scrupulously clean. Remove all carpets, upholstered furniture, and heavy hangings.

The floor should be bare, with only a few rugs to deaden sound.

The temperature of the room should receive careful attention under the direction of the physician.

Remove all offensive matters from the room immediately.

In cases of contagious disease, pieces of muslin used by the patient should be burned, and all dishes, spoons, and glasses should be put into boiling water before they are carried from the room.

The bed-linen and the clothing worn by the patient should be changed often, but it should be done with as little disturbance to the patient as possible.

These articles should be thoroughly disinfected by being put into boiling water to which some disinfectant has been added.

All medicine-bottles and other sick-room appliances should be kept out of sight of the patient, and all cups or glasses containing milk, water, or other drinks

should stand as far removed from the bed as possible. It is best to keep them in another room.

Keep the patient quiet. Sleep is Nature's great restorer, "sore labor's bath, the balm of hurt minds"; therefore the conditions for sleep should be as favorable as possible.

Rustling garments, creaking doors, whispering, etc., should be most carefully avoided. They irritate brain and nerves already rendered supersensitive by disease.

Be gentle and quiet in all your movements.

Use judgment and common sense in all that you do.

In the cases of chronic invalids, Florence Nightingale says that a few plants and a pet bird may be allowed in the sick-room, but in all other cases such things should be excluded. A tiny bouquet of freshly cut flowers, a bit of ice in a glass, a siphon-bottle on a daintily arranged table, are always grateful to a patient.

GLOSSARY.

Ab do'men. The largest cavity of the body, situated beneath the level of the diaphragm, containing the stomach, liver, intestines, etc.

Ab sorp'tion. The taking up of fluids by the blood-vessels and lymphatics.

Ac e tab'u lum. The cavity of the *os innominatum*, or hip-bone, which receives the head of the femur.

Ac'id. A substance usually sour, sharp, or biting to the taste.

Ad'am's ap'ple. The prominence on the forepart of the throat.

Al bi'no. A person of pale, milky complexion, with light hair and pink eyes.

Al bu'min. A nitrogenous substance extensively diffused in the animal and vegetable kingdoms, and coagulable by heat.

Al bu'mi noids. A class of substances resembling albumin ; they may be derived from the animal or vegetable kingdom.

Al'co hol. The intoxicating element of spirituous liquors.

Al i men'ta ry ca nal'. The digestive tract of any animal.

Al'ka li. The name given to certain substances, as soda, potash, and the like, which have the power of neutralizing acids.

A mœ'ba. One of the lowest of animal organisms.

A nat'o my. The science of the structure of organized bodies.

An es thet'ic. A medicinal agent which induces a state of insensibility, especially to pain.

A or'ta. The main trunk of the arterial system.

Ap'o plex y. A sudden loss of consciousness, due to the bursting of a blood-vessel in the brain.

Ap pa ra'tus. A number of organs, differing in size and structure, which work together for the accomplishment of a particular object.

Ap pen'dix ver mi for'mis. A small projection from the cæcum.

A'que ous hu'mor. A watery, colorless fluid occupying the space between the cornea and crystalline lens of the eye.

Ar'bor vi'tæ. The arborescent appearance of a section of the cerebellum.

Ar'te ry. A blood-vessel carrying blood away from the heart.

Ar tic u la'tion. The movable union of bones ; a joint.

A ryt'e noid car'ti la ges. Two small cartilages at the top of the larynx.

As sim i la'tion. The conversion of food into living tissue.

As tig'ma tism. A defect in the refractive apparatus of the eye.

Au'di to ry nerve. The nerve of hearing.

Au'ri cle. The upper cavity of the heart on each side.

Bac te'ri a. Microscopic vegetable organisms, shaped like rods. Certain species are active in fermentation, while others are believed to be the cause of many diseases.

Bi'ceps. A large muscle situated on the front of the arm, extending from the shoulder to the elbow, and serving to bend the elbow-joint.

Bi cus'pid. The name of the fourth and fifth teeth on each side of the jaw; a valve in the left side of the heart.

Bile. The gall, or peculiar secretion of the liver ; a sticky, yellowish fluid, very bitter to the taste.

Bow'el. A division of the alimentary canal below the stomach.

Brain. The soft gray and white matter, consisting of ganglionic nerve-cells and nerve-fibers, contained in the cavity of the skull.

Bron'chi al. Relating to the bronchi.

Bron chi'tis. Inflammation of the mucous membrane lining the bronchi.

Bron'chus. The first division of the trachea, one division passing to each lung.

Buc'cal. Pertaining to the cheek.

Bun'ion. An enlargement and inflammation of the bursa over the first joint of the great toe.

Cæ' cum. The beginning of the large intestine.

Cal'i ces; pl. of calyx. The cup-like beginnings of the ureters, surrounding the apices of the Malpighian pyramids.

Cal'lus. *I.* Any excessive hardness of the skin caused by pressure or friction. *II.* A sticky, gelatinous substance thrown out around the ends of broken bones.

Ca nal'. Any tube or passage in the body.

Can a lic'u lus. A small groove.

Ca nine'. The sharp, pointed tooth on each side of the incisors.

Cap'il la ry. The smallest blood-vessel, connecting the arteries and veins.

Cap'su lar lig'a ment. The ligament that surrounds the ball-and-socket joints, and, like a bag, contains the synovial fluid.

Car'bon di ox'id or

Car bon'ic ac'id gas. A gas containing one part of carbon to two of oxygen.

Car'di ac. Pertaining to the heart; the upper orifice of the stomach, through which the food enters from the œsophagus.

Ca rot'id ar'te ries. The large arteries supplying the brain and front of the head and face.

Car'ti lage. A tough, elastic substance attached to the bones, forming a part of the joints, air-passages, nostrils, and ears.

Ca'se in. The albuminoid substance of milk forming the basis of cheese.

Cat'a ract. A disease of the eye.

Ca tarrh'. An inflammation of a mucous membrane.

Cell. The name of the microscopic elements which, with slender fibers, make up most of the body.

Cer e bel'lum. The little brain.

Cer'e brum. The brain proper, occupying the entire upper portion of the skull.

Chest. The upper part of the trunk inclosed by the spinal column, the ribs, and the sternum, inclosing the lungs and the heart.

Cho'roid. The middle coat of the eyeball, containing pigment-cells and blood-vessels.

Chyle. The milk-like fluid formed by the digestion of fatty foods in the intestines.

Chyme. The food as it passes from the stomach into the small intestines.

Cil'i a. Minute hair-like processes attached to cells of air-passages.

Cil'i ar y mus'cle. A small, circular muscle attached to the choroid coat of the eyeball.

Cil'i a ted ep i the'li um. Any variety of true epithelium, the cells of which are furnished on their free surfaces with cilia.

Cir cu la'tion. The course of the blood through the heart and blood-vessels of the body.

Cir cum val'late. The name of the large papillæ on the back part of the tongue.

Clav'i cle. The long, slender bone extending across the upper part of the chest, joining the scapula or shoulder-bone and the sternum or breast-bone; the collar-bone.

Clot. The jelly-like mass formed by the coagulation of the blood.

Co ag u la'tion. Applied to the process by which blood clots.

Coc'cyx. The part of the spinal column consisting of the last four bones.

Coch'le a. The spiral cavity of the internal ear.

Com bus'tion. A process taking place in the body by which the tissues are consumed, to be replaced by new elements.

Con'cha. The outer ear.

Con ges'tion. An unnatural accumulation of blood in any organ or part of the body.

Con junc'ti va. The mucous membrane which lines the inner surface of the eyelids and thence is reflected over the front of the eyeball, thus joining the lids with the globe of the eye.

Con nec'tive tis'sue. A tissue composed of spindle-shaped and branching cells with an intercellular substance of fibrils.

Con sump'tion. Specifically, a disease of the lungs accompanied by fever, cough, and emaciation.

Con trac til'i ty. The property of a muscle which enables it to shorten under appropriate stimulus.

Con'vex. Curved, like the outside of a globe.

Con vo lu'tions. The tortuous foldings of the external surface of the brain.

Con vul'sion. A violent and involuntary contraction with alternate relaxation of the muscular parts of the body.

Co'ri um. The innermost layer of the skin.

Corn. A thickening of the epidermis, usually with a central core, or nucleus.

Cor'ne a. The firm, transparent membrane which forms the front of the eyeball.

Cor'pus cles. *I.* The minute disks, concave on both sides, which give to the blood its red color; the large, white, globular bodies which the blood contains. *II.* Tactile corpuscles. Small, oval bodies composed of connective tissue, and supplied with one or more nerve-fibers.

Cra'ni al. Pertaining to the skull.

Cra'ni um. The skull.

Cri'coid. A cartilage of the larynx, resembling a seal-ring.

Crys'tal line lens. A double-convex body composed of a transparent, firm substance, inclosed in a membranous capsule, and situated in front of the vitreous body and behind the iris of the eye.

Cus'pid. A pointed tooth next back of the incisors; the canine.

Cu'ti cle. Scarf-skin; the epidermis.

Cu'tis. The true skin, containing the hair-bulbs, blood-vessels, nerves, etc.

Dan'druff. A scurf which forms on the scalp, or skin of the head.

De cus sa'tion. The reciprocal crossing of fibers of nerves from side to side.

De gen er a'tion. Any process by which the tissue or substance of any organ is replaced by some other of inferior physiological rank.

Deg lu ti'tion. The act of swallowing.

De lir'i um. A disordered state of the mental faculties.

De lir'i um tre'mens. A disorder of the brain which arises from an inordinate use of alcoholic drinks.

Den'tin. The proper substance of the tooth.

Di'a phragm. A large, thin muscle which separates the thoracic from the abdominal cavity.

Di ges'tion. The process of converting the food from the state in which it enters the mouth to that in which it can pass from the alimentary canal into the blood-vessels and lymphatics.

Dis lo ca'tion. The putting out of joint.

Dis sec'tion. The process of cutting into parts in order to show structure.

Dor'sum. The back of an organ.

Drum of ear. The membrane which separates the middle ear from the external ear and on which the sound-waves first strike.

Duct. A tube, or canal, of an animal, by which blood or chyle, lymph, secretions, etc., are conveyed.

Du o de'num. The first division of the small intestine.

El'e ment. One of the simplest parts of which anything consists.

E mul'sion. A mixture of liquids insoluble in one another, one being suspended in the other in the form of minute globules.

En am'el. A dense, smooth, glistening substance which covers the crown of a tooth.

Ep i dem'ic. A temporary prevalence of a disease.

Ep i der'mis. The outer layer of the skin.

Ep i glot'tis. A valve-like organ situated at the base of the tongue, just above the glottis.

Ep'i lep sy. A disease of the brain, characterized by loss of consciousness and sometimes by muscular spasms.

Ep i the'li um. The superficial layer of cells of mucous membrane which covers the free surfaces of the body, and forms the glands and other organs derived from these coverings.

E'ther. A light, mobile, colorless liquid, having a characteristic odor and a burning taste.

Eth'moid. A bone of the cranium, perforated for the passage of the olfactory nerves.

Eu sta'chi an tube. The tube leading from the middle ear to the pharynx.

Ex cre'tion. The separation of the waste matters of the body from the blood; the materials excreted.

Ex pan'sion. The act of extending, or spreading out.

Ex pi ra'tion. The expulsion of air from the lungs in the process of respiration.

Ex ten'sor. A muscle which serves to extend or straighten any part of the body.

Fa'cial nerve. The motor nerve of the face.

Fang. The long, pointed root of a tooth.

Far i na'ceous. *I.* Consisting of meal or flour. *II.* Containing starch.

Fas'ci a. A dense sheet of connective tissue enveloping muscles.

Fau'ces. The back part of the mouth, leading into the pharynx.

Fem'o ral ar'te ry. The main artery of the thigh.

Fe'mur. The thigh-bone.

Fe nes'tra. The opening between the middle and internal ear.

Fe nes'tra o va'lis. An opening into the vestibule of the ear from the tympanic cavity.

Fer'ment. That which causes fermentation.

Fer men ta'tion. A decomposition produced in an organic substance by the physiological action of a living organism or by certain unorganized agents.

Fi'ber. A microscopic thread of nitrogenous matter, very tough, strong, and elastic.

Fi'bril. One of the fine longitudinal threads of muscular fibers; one of the filaments which constitute the axis-cylinder of a nerve.

Fi'brin. An organic compound found in animals and vegetables.

Fi'bri no gen. A proteid substance belonging to the group of globulins.

Fi'bro-car'ti lage. A tissue intermediate between cartilage and ligament.

Fi'brous tis'sue. The general connective tissue of the body.

Fib'u la. The outer and smaller bone of the leg.

Fil'a ment. A separate fiber or fibril of any animal or vegetable tissue.

Fis'sure. A natural division or groove between adjoining parts of like substance.

Flex'ion. The act of bending a limb.

Fo'cus. The point at which rays of light meet after passing through a convex lens or being reflected from a concave mirror.

Fol'li cle. A minute secretory or excretory sac or tube.

Fo men ta'tion. The act of applying warm liquids to a part of the body by means of flannels, etc., dipped into them.

Fo ra'men. An orifice or fissure through a bone or other structure, or between contiguous bones, giving passage to a vessel or nerve.

Fo've a cen tra'lis. A little pit in the middle of the yellow spot of the retina.

Fron'tal si'nus es. Cavities in the bones of the skull, just over the eyebrows.

Func'tion. Special work of any organ of the body.

Fun'gi form. Having the form of a mushroom.

Gall. The bitter secretion of the liver.

Gall-blad'der. The receptacle of the bile.

Gan'gli on. An enlargement in the course of a nerve.

Gan'gli on im'par. The single ganglion in which the two chains of sympathetic ganglia terminate posteriorly; the end of the sympathetic system, behind.

Gas'tric. Pertaining to the stomach.

Gas'tric juice. The fluid secreted by the stomach.

Gel'a tin. A nitrogenous substance obtained from bone, ligaments, connective tissue, etc.

Germ. A microbe; disease-germ: a name applied to certain microscopic, bacterial organisms which have been demonstrated to be the cause of many diseases.

Gland. An organ consisting of follicles and ducts and numerous blood-vessels, and secreting or excreting a substance peculiar to itself.

Glob'u lin. A general name of a class of substances allied to the albumins, but distinguished from them by being insoluble in pure water.

Glot'tis. The opening from the pharynx into the trachea.

Glu'cose. The name of a group of sugars one or more of which constitute the sugar of fruits; the sugar elaborated by the liver.

Glu'ten. The nitrogenous part of the flour of wheat and other grains which is insoluble in water.

Gus ta'tion. The sense of taste; the act of tasting.

Gus'ta to ry nerve. The nerve of taste supplying the front part of the tongue. It is a branch of the "fifth" pair of cranial nerves.

Ha ver'sian ca nals'. (Discovered by Clopton Havers, a London anatomist.) Minute canals containing medullary matter, and occurring in the substance of bone.

Hem'a tin. The coloring matter of the blood.

Hem'i spheres. The lateral halves of the cerebrum.

Hem o glo'bin. The red semi-fluid substance which forms about nine-tenths of the dry constituents of the red blood-corpuscles and serves as the carrier of oxygen in the circulation.

Hem'or rhage. A discharge of blood from blood-vessels, either external or internal.

He pat'ic. Pertaining to the liver.

He red'i ty. The law by which living beings tend to repeat themselves in their descendants.

Hic'cough. A quick, involuntary, inspiratory movement of the diaphragm brought suddenly to a stop by an involuntary closing of the glottis.

Hu'me rus. The bone of the arm, from the shoulder to the elbow.

Hu'mor. An animal fluid, whether natural or morbid.

Hy'dro gen. A gas; the lightest of the elements: one of the constituents of water.

Hy dro pho'bi a. A disease caused by the bite of a rabid dog or other animal.

Hy'gi ene. The department of medical knowledge which concerns the preservation of the health.

Hy'oid bone. The tongue-bone.

In ci'sors. The front teeth.

In'cus. One of the bones of the inner ear of a mammal.

In'dex-fin'ger. The forefinger.

In di ges'tion. A condition in which the food is not properly digested, or is digested with difficulty.

In fe'ri or ve'na ca'va. The chief vein in the lower part of the body.

In flam ma'tion. A diseased condition of the body, usually characterized by swelling, pain, heat, and redness.

In sal i va'tion. The process of mixing the saliva with the food in the act of eating.

In spi ra'tion. The act of drawing in the breath.

In teg'u ment. The skin or outer covering of any animal or vegetable body.

In ter cel'lu lar. Situated between or among cells.

In ter cos'tal mus'cles. Muscles which lie between the successive ribs on the same side of the body.

In ter'nal ear. The part of the ear that is imbedded in bone, in which the branches of the nerves of hearing are distributed.

In tes'tine. The lower part of the alimentary canal, which is continuous with the pyloric end of the stomach.

In tus sus cep'tion. Reception of foreign matter by living organisms and its conversion into living tissue.

In ver'te brate. A term applied to animals having no backbone.

In vol'un ta ry. Without the consent of the mind or will.

I'ris. A contractile, colored curtain which lies between the cornea and the crystalline lens, and gives color to the eye.

Jaun'dice. A disease characterized by the presence of the coloring matter of the bile in the blood, which coloring matter changes the skin and "whites" of the eyes to a dark yellow.

Joint. The union of two bones so as to admit of motion.

Ju'gu lar. The name of the chief veins of the neck, which carry the blood from the head back to the heart.

Kid'neys. Two important excretory organs, glandular in structure, situated in the back part of the abdominal cavity.

Lab'y rinth. The internal ear; the essential organ of hearing.

Lach'ry mal (also lacrimal). Pertaining to tears.

Lach'ry mal duct. The nasal duct which conveys tears from the eye to the nose.

Lac'te als. That portion of the lymphatic system which conveys the chyle from the intestines to the thoracic duct.

Lac'tic ac'id. An acid formed in milk when it becomes sour.

La ryn'go scope. An instrument for examining the larynx and trachea.

Lar'ynx. The upper part of the trachea, in which the vocal cords are situated; the organ of voice.

Lens. A transparent substance bounded by two curved surfaces, or by a curved surface and a plane, so that light passing through it is refracted; *i.e.*, bent out of its course.

Le va'tor. That which raises or elevates.

Lig'a ture. Anything that serves for tying, binding, or uniting an injured blood-vessel so as to prevent hemorrhage.

Liv'er. A large gland secreting bile, and performing other important functions.

Lobe. A large natural division of an organ.

Lum ba'go. A rheumatic disease of the muscles in the lumbar region.

Lungs. The organs of respiration, which occupy the thorax.

Lymph. The colorless, transparent fluid contained in the lymphatics.

Lym phat'ics. A system of absorbent vessels consisting of capillaries and ganglia.

Mac'u la lu'te a. The yellow spot of the retina of the eye.

Ma'lar. A short, stout bone forming the prominence of the cheek.

Mal'le us. One of the bones in the middle ear.

Mal pigh'i an cap'sules. Globular dilatations in the kidneys.

Mam ma'li a. The highest class of vertebrata.

Mar'row. A soft, fatty substance contained in the cavities of the long bones.

Mas se'ter mus'cle. One of the principal muscles of mastication. It is attached to the skull and to the lower jaw, and is used in closing the jaw.

Mas ti ca'tion. The act of chewing.

Max il'la. The name of the upper and lower jawbones.

Me a'tus. A passage: applied to various ducts of the body.

Me dul'la ob lon ga'ta. The continuation of the spinal marrow which enters the skull.

Med'ul la ry. Resembling marrow.

Mem'brane. A thin, soft, transparent sheet of tissue which wraps and protects various organs, or lines cavities in the body.

Mem'brane of Cor'ti. A strong, elastic membrane in the cochlear canal of the ear.

Mem'brane, tym pan'ic. A delicate partition separating the outer from the middle ear.

Men o bran'chus. A genus of tailed amphibians characterized by the persistence of the gills.

Mes en ter'ic glands. The lymphatic glands of the mesentery.

Mes'en te ry. The membrane which attaches the small intestine to the back wall of the abdomen.

Met a car'pal. The name of the bones between the wrist and the fingers.

Met a car'pus. The part of the hand between the wrist and the fingers.

Met a tar'sal. The name of the bones in the foot between the ankle and the toes.

Met a tar'sus. The part of the foot between the ankle and the toes.

Mi'crobe. A microscopic organism. It is instrumental in the production of fermentation and decay, and of many of the infectious diseases affecting man and the lower animals.

Mi'tral. The name of the valve between the left auricle and ventricle in the heart.

Mo'lars. The back teeth, especially those which are not preceded by milk-teeth.

Mo'tor. The name given to those nerves whose function is to excite muscular contraction or motion: opposed to sensory.

Mu'cous mem'brane. The lining of the cavities of the body which communicate with the exterior.

Mu'cus. A viscid fluid secreted by the mucous membrane.

Mus'cle. An organ of motion in an animal body.

My'e lin. A white substance which surrounds the axis-cylinder; the medullary sheath of a nerve.

Nar cot'ic. Any substance which dulls sensibility and induces sleep.

Na'res. The nasal cavities.

Na'sal. Pertaining to the nose.

Nerve. A fiber, or a bundle of fibers, which runs from the brain or spinal cord to different parts of the body and establishes communication between these organs and the central ganglia.

Nerve-cell. Any cell constituting a part of the nervous system.

Nerve-cen'ter. A group of ganglion-cells connected with one another and acting together.

Neu ri lem'ma. The delicate fibrous sheath of a nerve-fiber.

Neu rog'li a. Nerve-glue; a supporting network of the cerebrospinal axis.

Newt. A tailed batrachian.

Nic'o tine. A volatile alkaloid liquid obtained from tobacco.

Ni'tro gen. A gaseous element.

Nu'cle us. A central mass of protoplasm found in nearly all cells, supposed to maintain the life of the cell and to give rise to new cells by division.

Nu tri'tion. The process by which vegetable and animal organisms absorb into their systems proper food.

Oc cip'i tal. Pertaining to the back of the head.

Oc'ci put. The part of the skull which forms the back part of the head.

O don'toid proc'ess. A tooth-shaped peg on the vertebral axis.

Œ soph'a gus (also esophagus). The canal through which food and drink pass to the stomach.

O le ag'i nous. Having the qualities of oil.

Ol fac'to ry. Pertaining to the sense of smell.

Op'tic. Pertaining to sight.

Or'bit. The bony hollow in which the eyeball rests.

Or'gan. One of the parts of an organized body which performs some special function.

Os mo'sis. The intermixture or diffusion of liquids which takes place through a moist membrane.

Os'se ous. Bony; made of bone.

Ox'y gen. One of the gaseous elements.

Pal'ate. The roof of the mouth. The bony portion is called the hard palate, and the fleshy membrane attached to this and hanging between the mouth and the pharynx is called the soft palate.

Pal pi ta'tion. A violent, unnatural beating of the heart.

Pan'cre as. An important gland which aids in the digestion of food, especially the fatty matters.

Pa pil'læ. Conical elevations on the surface of the derma, containing the terminations of the nerves and blood-vessels.

Par a glob'u lin. A globulin found in the blood-serum, and in the tissues in small quantities.

Pa ral'y sis. Loss of function, especially loss of motion or feeling.

Par'a site. A plant or animal that lives on another.

Pa ri'e tal. The name of the two bones of the cranium forming a part of the top and sides of the skull between the occipital and frontal bones.

Pa rot'id gland. A salivary gland situated below and in front of the ear.

Pa tel'la. The knee-cap.

Pel'vis. The bony basin at the base of the trunk.

Pep'sin. One of the constituents of the gastric juice.

Pep'tic glands. Glands in the mucous membrane of the stomach which secrete the gastric juice.

Pep'tone. The name of a class of albuminoids into which the nitrogenous elements of food are converted by the action of gastric or pancreatic juice.

Per i car'di um. The membranous bag which incloses the heart.

Per i os'te um. The thin membrane which covers the bones.

Per i stal'tic. Contracting in successive circles: applied to the slow wave-like movements of the muscular lining of the stomach and intestines.

Per i to ne'um. The serous membrane covering the abdominal organs.

Pe'trous. The part of the temporal bone which contains the auditory organs.

Pha lan'ges. The small bones of the fingers and toes.

Phar'ynx. The cavity into which the mouth, nose, upper end of the alimentary canal, and the trachea open.

Phy si ol'o gy. The science which treats of the organs and their actions in living, organized beings; the science of vital power.—Huxley and Youman's "Physiology."

Pig'ment-cells. The cells which secrete coloring matter.

Plas'ma. The liquid part of the blood, lymph, or milk, as distinguished from the corpuscles of the blood or lymph, or the oil-globules of milk.

Pleu'ra. The serous membrane which invests the lungs and lines the thorax.

Pleu'ri sy. Inflammation of the pleura.

Plex'us. An interlacing of nerves, vessels, or fibers.

Pneu mo gas'tric nerves. The principal nerves of respiration.

Pneu mo'ni a. Inflammation of the air-cells of the lungs.

Pons Va ro'li i. A mass of brain-substance which connects the cerebrum, cerebellum, and the medulla oblongata.

Por'tal vein. The large vein which carries the blood from the digestive organs through the liver to the heart.

Pro'te id. A class of substances composed of carbon, hydrogen, oxygen, and nitrogen; an albuminoid.

Pro'to plasm. An albuminoid substance consisting of carbon, nitrogen, oxygen, and hydrogen, capable of manifesting certain vital phenomena.

Pty'a lin. A constituent of saliva.

Pul'mo na ry. Pertaining to the lungs: the name of the blood-vessels which carry the blood from the heart to the lungs and back again to the heart.

Pu'pil. The opening in the iris, through which the light passes.

Py lo'rus. The opening from the stomach into the duodenum.

Ra'di us. The outer bone of the forearm.

Ra'di al ar'te ry. The artery lying on the radial side of the forearm.

Re'flex ac'tion. The involuntary movements produced by a stimulus transmitted along sensory nerves to a nerve-center, from which it is again reflected along motor nerves.

Re'nal. Pertaining to the kidneys.

Res pi ra'tion. The inspiration and expiration of air; act of breathing.

Ret'i na. The expansion of the optic nerve. It forms the innermost lining of the eyeball.

Rick'ets. A disease in which the bones soften and become distorted.

Rig'or mor'tis. The characteristic stiffening of the body, caused by the contraction of the muscles after death.

Sac'cha rin. Applied to those food-substances which include the different varieties of sugar, starch, and gum.

Sac'cu lus. A little sac or cell.

Sa'crum. A compound bone near the lower end of the spine, to the sides of which are attached the hip-bones.

Sal'a man der. A kind of lizard.

Sa li'va. The secretion of the salivary glands and of the mucous membrane of the mouth.

Sar co lem'ma. The sheath which covers each fiber of muscular tissue.

Scap'u la. The shoulder-blade.

Scle rot'ic. The tough white outer coat of the eyeball.

Se ba'ceous. The name of the glands which usually open into hair-follicles and secrete an oily matter.

Se'bum. The secretion of the sebaceous glands.

Se cre'tion. The process of preparing and separating substances from the blood by means of glands.

Sem i cir'cu lar ca nals'. The three canals of the internal ear.

Sem i lu'nar valves. Valves at the junction of the aorta and the left ventricle and the pul-

monary artery and the right ventricle.

Sen sa'tion. The perception of an external impression by the nervous system.

Sen'so ry nerves. Nerves which convey sensation.

Sep'tum. A partition between two cavities.

Se'rum. The clear, yellowish fluid which separates from the clot in coagulation of the blood.

Skel'e ton. The bony framework of the body which sustains, incloses, or protects the soft parts, or vital organs.

Skull. The brain-case.

Sphe'noid. One of the important compound bones on the under side of the skull.

Spi'nal ca nal'. The cavity containing the spinal cord.

Spi'nal cord. The spinal marrow which extends from the brain and occupies the spinal canal.

Spleen. One of the largest ductless glands, situated on the left side of the stomach in the abdominal cavity.

Sta'pes. The innermost of the small bones of the ear.

Ster'num. The breast-bone.

Stim'u lus. Something that excites some functional reaction in the tissues on which it acts.

Stri a'tions. The stripes characteristic of the voluntary and of a few of the involuntary muscles.

Stro'ma. The sustaining tissue of an organ.

Sub cla'vi an. Lying under the clavicle.

Sub lin'gual. Situated under the tongue.

Sub max'il la ry. Situated beneath the jaw.

Su do rip'a rous. The name of the glands of the skin which secrete perspiration.

Sul'ci. Grooves on the surface of the brain.

Su'ture. The immovable joint of certain bones of the skull.

Sweat'-gland. The lower end of the sweat-tube which secretes sweat.

Sym pa thet'ic sys'tem. A double chain of ganglia along the spinal column.

Sy no'vi al mem'brane. The membrane which lines the joints and secretes the glairy substance which lubricates them.

Sys'to le. The contraction of the heart by which the blood is expelled from that organ.

Tac'tile. Pertaining to the sense of touch.

Tar'sal. The name of the bones in the ankle-joint between the tibia and the metatarsus.

Tem'po ral. Pertaining to the temples.

Ten'don. A band of dense fibrous tissue which connects the muscles with the bones; a sinew.

Tho rac'ic duct. The large tube into which most of the smaller lymphatics pour their contents.

Tho'rax. The cavity containing the heart and lungs.

Thy'roid. The largest of the cartilages of the larynx, forming the projection in the front, called "Adam's apple."

Tib'ia. The shin-bone.

Tis'sue. The grouping of elemental substances of which any part of the body is composed, so united as to form one structure.

Ton'sils. Two oval glands situated in the back part of the mouth.

Tra che'a. The windpipe.

Tri'ceps. The large extensor muscle on the back of the arm.

Tri cus'pid valve. The valve between the right auricle and ventricle of the heart.

Tu'bule. A small tube or pipe.

Tur'bi nal bones. The spongy scroll-like bones in the nasal passages.

Tym'pa num. The middle ear.

Ul'na. The large bone of the forearm.

U're a. One of the chief solid constituents of the urine.

U re'ter. The excretory duct of the kidneys.

U'tri cle. The common sinus of the inner ear; the larger of the two sacs in the vestibule of the membranous labyrinth of the ear.

U'vu la. The prolongation of the soft palate.

Vas'cu lar. Pertaining to vessels which convey fluids; pertaining to the circulation of fluids, especially blood, lymph, and chyle.

Vas o mo'tor nerves. The nerves which control the circulatory vessels.

Ve'nous. Pertaining to veins.

Ven'tri cles. The two chambers in the heart which receive the blood from the auricles and propel it into the arteries.

Ver'te bra. A joint of the spinal column.

Ves'ti bule. A part of the labyrinth of the ear between the semicircular canals and the cochlea.

Vil'lus. A minute thread-like process of the mucous membrane lining the small intestines.

Vis'ce ra. The contents of the abdomen.

Vit're ous hu'mor. The contents of the posterior chamber of the eyeball.

Vo'cal cords. The elastic bands in the upper part of the larynx, whose vibrations cause the voice.

Vol'un ta ry. Applied to actions performed in obedience to the will.

Yeast. A fungous growth consisting of minute vegetable cells.

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